BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 13

Contribution from the Forest Service, Henry S. Graves, Forester.
February 24, 1914.

WHITE PINE UNDER FOREST MANAGEMENT.

By E. H. Frothingham, *Forest Examiner.*

SUITABILITY OF WHITE PINE FOR MANAGEMENT.

Of all the trees of eastern North America white pine best combines the qualities of utility, rapid growth, heavy yield, and ease of management. Its former abundance and the cheapness and varied usefulness of its lumber made it an important factor in the development of the States in which it grew and even of regions far outside of its natural range. After an enormous and for a long time unapproached exploitation the original forests are now approaching exhaustion, and the large-size high-grade white pine lumber, once abundant on the market, has become scarce and expensive. With its decline, lower grades have come into existence and have found a ready market where large size and high quality are not essential.

The demand for low-grade white-pine lumber has made it possible, from a business standpoint, to cut and market second-growth white pine when comparatively small and young. For many years the pine output of the Northeastern States has consisted almost wholly of second growth, most of it cut in limited tracts or woodlots by small portable mills. Thousands of such stands exist on abandoned farms or pastures in New England. In other regions white pine has sprung up in abundance after lumbering and needs only time and protection from fire to develop into thrifty, valuable stands. Had fires not been allowed to run repeatedly over the slash left in logging the original stands, a large part of northern Michigan and other noted white-pine regions would probably now be covered with pine second growth, much of it already of merchantable value.

Because of the success with which white pine lends itself to management, the relatively steady market, and the small amount of waste in lumbering, there is no doubt that under widely varying conditions of quality and accessibility, and with the prevailing tax rates, market value, and wages, the raising of white pine to ages of from 35 to 70 years is a profitable undertaking at 4, 5, 6, and sometimes 10 per cent compound interest.

This bulletin summarizes the most important facts relative to white pine, with regard both to the original forest and to the second growth. The yield tables for second-growth stands presented in the bulletin are based on measurements made in southern New Hampshire by C. A. Lyford and Louis Margolin. These may be considered as roughly applicable to second-growth stands throughout most of the range of white pine. From them have been derived tables showing the value of stumpage at prevailing prices and the profit or loss resulting from the management of second growth under favorable and unfavorable conditions. Methods are also suggested for securing successive crops and for increasing the quantity and quality of the yield. The chapters on "Direct Seeding" and "Protection" are from an unpublished report on white pine by A. K. Chittenden and J. S. Ames.

GEOGRAPHICAL RANGE.

White pine grows in general from Newfoundland to southeastern Manitoba; thence southeastward through Minnesota and central Wisconsin, with detached groves as far south as central and eastern Iowa, southern Wisconsin, and northern Illinois; and eastward through southern Michigan and along the northern shore of Lake Erie to New York. It is found in the northeastern corner of Ohio and throughout the Appalachian Mountains as far south as Alabama and Georgia. It is abundant throughout New England, New York, and Pennsylvania, and on the Atlantic coast reaches its southern limit in central New Jersey.

The presence of white pine in this region is doubtless due to the cool, moist climate. The cold climate farther north, the warm one to the south, and the dry one to the west are all inhospitable to white pine because their soils do not supply enough moisture for transpiration. In the North this is due to the low temperature of the soil moisture during much of the year and to low atmospheric humidity, in the West to light precipitation and dry winds, and in the South chiefly to the high temperature and low relative humidity of the air. In the Appalachians suitable climatic conditions exist at increasingly high altitudes as one goes south, so that while in the North white pine is common at sea level in Alabama and Georgia it does not thrive below an altitude of 2,500 or 3,000 feet.

One of the factors responsible for the commercial importance of white pine was its abundance. Thus, while the usefulness of the lumber caused small tracts of white pine or even individual trees to be highly prized in regions where pine was scarce, it was in the dense pineries, and where the tree grew abundantly among hardwoods, that white-pine lumbering assumed importance. The region in which white pine was especially abundant comprised the New England

States, New York, Pennsylvania, the Lake States, and southern Quebec and Ontario south of the "Height of Land."

In New England white pine seldom formed solid bodies of large extent, but usually grew mixed with spruce and other conifers and hardwoods. In several places, however, large pure stands of white pine were found. Great pine forests stretched along the valleys of the Connecticut and Merrimac Rivers and grew along the shores of Lake Champlain in western Vermont.

White pine was abundantly scattered, either individually or in small stands, throughout the hardwood forests of the Adirondack region in New York; was conspicuous along the Hudson River and in the Catskills; and was found on occasional sandy plains or on elevations throughout the broadleaf forests which covered the remainder of the State. In Pennsylvania vast forests of white pine and hemlock covered both flanks of the Allegheny Mountains, and occasional groves existed among the heavy forests of hardwoods and hemlock east and west of the Allegheny region. The headwaters of the Susquehanna River were heavily wooded with white pine.

The densest and most extensive forests of white pine were those in Michigan. As compared with New England the topography there is level, and favorable conditions for the growth of white pine existed over wide areas. It was abundant in the northern part of the lower peninsula, where on the sandy soils it grew in immense practically pure forests, and on the heavier loams interspersed among hardwoods. In the northern peninsula, especially in the basin of the Menominee River, it covered the sandy plains almost to the exclusion of other species.

In Wisconsin there were fewer pure stands of white pine than in Michigan, though some could be found in gravelly or sandy regions in many parts of the State. In mixture with hardwoods and other conifers, however, white pine was very abundant.

The pine forests of Minnesota were confined to the northern and central portions of the State. They were not so extensive as those in Michigan, but, as elsewhere in the Lake States, white pine was very prominent in mixture with hardwoods.

White pine was not abundant in the Southern Appalachians, and the few pure stands were confined to some of the higher moist valleys. In these the timber was often of the finest quality, with dominant trees ranging from 100 to 200 feet in height. Few stands, however, exceeded a cut of 25,000 board feet per acre, and the yield was ordinarily not more than from 2,500 to 5,000 feet. The proportion of good lumber in southern-grown white pine is not as high as in the trees grown in the North.

It has been estimated that the original stand of pine in the Lake States (including Norway pine) amounted to more than

350,000,000,000 board feet. Of this it is stated Michigan had about 150,000,000,000 feet, Wisconsin about 130,000,000,000, and Minnesota about 70,000,000,000. Since lumbering began not less than 250,000,000,000 feet have been cut and perhaps 100,000,000,000 feet burned. In 1880 the census estimate of the stand was less than 88,000,000,000 board feet, but according to the annual reports of the American Lumberman the cut since then has exceeded 170,000,000,000. In 1900 the census estimated the stand at 50,000,000,000, and in 1903 R. A. Long placed it at 60,000,000,000 feet. According to data compiled by R. S. Kellogg, of the Forest Service, the lumber production of all species in the Lake States between 1880 and 1910 was:

Michigan: 103,525,000,000 board feet; about 75 per cent white pine.
Wisconsin: 80,385,000,000 board feet; about 80 per cent white pine.
Minnesota: 44,890,000,000 board feet; about 95 per cent white pine.

Of the total production of lumber in the United States during these 30 years white pine furnished 14 per cent, or 58,000,000,000 board feet.

The amount of privately owned pine (white and Norway) now standing in the Lake States is estimated by the Bureau of Corporations[1] as:

	Board feet.
Michigan	2,000,000,000
Wisconsin	3,200,000,000
Minnesota	12,500,000,000

There is some reason to believe that the total quantity in Wisconsin is understated. The proportion of white pine comprised in the stand, for the States named, is tentatively placed at 79, 83, and 64 per cent. White and Norway pine together formed, respectively, 4.2, 11, and 53.9 per cent of the total stand of timber in the States listed, or a total of about 18 per cent of the Lake States forest. On the basis of these figures the present annual cut of pine is comparatively large. The cut for the year 1909, according to the Bureau of Corporations, took 12.3 per cent of the standing pine in the Lake States: 12.9 per cent of that in Michigan, 19.1 per cent in Wisconsin, and 10.5 per cent in Minnesota. For Wisconsin the percentage may be somewhat too high, since it is based on a very conservative stand estimate.

WHITE PINE AND THE LUMBER INDUSTRY.

The history of white-pine lumbering begins with the first settlement of the country. In 1623 mills were set up in New York, and by 1635 white pine was being exported from New England. At that early date little was known as to the available supply, even in the country close to the shipping points, and in 1650 fears were ex-

[1] Report on the Lumber Industry, Part I, Standing Timber, Jan. 20, 1913.

pressed in New England that the timber would soon be exhausted. For more than two centuries, however, the white-pine forests of the Eastern States yielded an ever-increasing output of lumber. The Louisiana Purchase in 1803 opened up in New Orleans a profitable market for the white pine of southwestern New York and northwestern Pennsylvania, and immense rafts of logs were floated down the Ohio and Mississippi Rivers from the region about the headwaters of the Allegheny.

White-pine lumbering began in Michigan and Wisconsin in the decade between 1820 and 1830, but it was not until after the latter date that any considerable quantity was cut. By 1840 enough was known of the extent of the Lake State pineries to bring lumbermen from the Eastern States, where a shortage of supply was already imminent. For over 40 years the white-pine industry of the Lake States continued to increase in volume until the annual production in Michigan alone reached a total of nearly four and one-half billion feet.

In Minnesota active lumbering did not commence until about 1875, 5 or 10 years before the high mark of the output of Michigan was reached. By 1899 Minnesota stood second to Wisconsin in point of production, while Michigan had dropped to third place. Five years later Minnesota, with a cut of less than 2,000,000,000 feet, was first, and Wisconsin second, a relative position which they have since maintained. With the depletion of its forests Michigan rapidly lost importance as a pine-producing State, and now stands sixth in the list, with an annual cut not one-twentieth as great as in 1883.

In America, with its immense natural forests, the cost of raising timber has not been a factor in determining its value. Heretofore the supply has been relatively large as compared with the demand, and stumpage prices have been correspondingly low. More recently, however, the demand for some kinds of lumber has equaled and sometimes exceeded the available supply, and in some cases stumpage values now even exceed the total cost of raising the timber artificially. An example of a marked rise in stumpage is that of the Wisconsin pine lands purchased by Ezra Cornell in 1866 for 60 cents per acre or equivalent to from 5 to 10 cents per thousand board feet. Of the 500,000 acres thus bought one-fifth was sold in 1873 for $4 per acre, or about 30 or 40 cents per thousand feet. By 1905 practically all the land had been disposed of at a clear profit of nearly $5,500,000. Some of the last sales of stumpage were at prices ranging from $10 to $12 a thousand. Virgin white-pine stumpage may now bring as much as $20 a thousand, and in Wisconsin a stumpage price of $65 per thousand has been paid for selected trees. (See Pl. II.)

Repeated rises in the price of stumpage often led to undervaluation of white-pine stands. In Minnesota, for example, a stand purchased for $30,000 was within a few years refused for lump sums of $50,000,

$100,000, and $150,000, and was finally sold, on a stumpage basis of $2.25 per thousand for large and $2 for small logs (20 logs per thousand feet), for a total of $365,000. In another case the stumpage on a 30-acre tract of second-growth pine in New Hampshire was bought for $1,000. When cut and sawed the pine yielded 530,000 board feet, worth at least $5 per thousand on the stump, or in all $2,650. Such underestimates, often resulting in loss to the owner, are constantly being made. Usually the cause is ignorance either of the amount and quality of the timber or of how to determine its value. Farmers and owners of small woodlands in connection with other property are most likely to lose money in this way.

As might be expected, the decrease in the output of pine has been accompanied by an increase in the value of the lumber. Thus, while the production of pine has fallen off over 56 per cent since 1890, the mill value of the total annual cut has declined only about 35 per cent. The average mill value per thousand feet has increased 50 per cent.

The high-grade white-pine lumber once so widely used in house building and finish is now largely restricted to pattern making, sash and door manufacture, and other exacting uses. White-pine uppers bring $90, $100, and even $130 per thousand board feet. It is probable that these prices mark practically the upper limit for high-grade pine lumber. In the case of the lower grades, however, which comprise much the larger part of the lumber manufactured, prices will no doubt continue to rise as the supply becomes scarcer.

Even the high price of the best white-pine lumber would not, under present conditions, warrant private owners growing trees to the ages necessary to produce these grades. Within the relatively short rotations of 70 years or less, which at present appear to be the only ones under which white-pine management can be made profitable, only grades of moderate value can be produced. Most second-growth lumber is manufactured "round," or bark edged, and disposed of to box and match factories.

In New England, where the timber is practically all second growth, box-board lumber is purchased round edged, usually in thicknesses of $\frac{7}{8}$, 1, $1\frac{5}{8}$, or $2\frac{1}{8}$ inches. The demands of the box manufacturers are extremely moderate. The boards are first cut into box lengths and in the widths involving the least waste of material. Often the boards are tongued and grooved parallel to the bark "wane," which gives them a trapezoidal shape. Widths as small as 2 inches and lengths of 3 and 4 feet are often accepted, if they do not form too large a proportion of the total amount. Box boards $2\frac{1}{8}$ inches thick are resawed in the factory into two 1-inch boards. Box-board lumber usually brings from $14 to $18 per thousand feet f. o. b. local markets, the price varying with thickness and to some extent with quality. One-inch boards, commonly called "sidings," are the least valuable and rarely bring over $15 per thousand. They are more expensive to handle, and as few as possible are manufactured.

For match blocks clear, straight-grained lumber is required. As in box making, lumber $2\frac{1}{8}$ inches thick is the standard for match manufacture. It usually commands a price of $17 or $18 a thousand. Second-growth stands yield a small amount of material clear enough for match bolts. Match companies usually accept $2\frac{1}{8}$-inch round-edged lumber without careful grading, and dispose of the material unsuited for match blocks (often 70 or 80 per cent of the total) for boxes.

But little lumber clear and straight enough for sashes and blinds is produced in the average "pasture-pine" stand less than 60 or 70 years old. On good soils, however, the more rapid growing trees may yield clear, straight pieces long enough for the purpose. Such lumber, round edged and $1\frac{3}{8}$ or $1\frac{5}{8}$ inches thick, may command a price of from $25 to $35 a thousand, provided the clear lengths are 2 or more feet long and the knots small.

Square-edged second-growth pine timber 1 inch thick usually brings from $20 to $25 in the local markets, but the waste and expense involved in edging nearly or quite offset the difference in price as compared with round-edged box boards. The waste in edging is usually from 10 to 20 per cent, since the boards must have parallel edges, while in box lumber a considerable proportion of crooked boards is accepted. One-inch square-edged lumber is comparable to the standard grade of No. 2 common. It usually varies widely in quality.

GENERAL CHARACTERISTICS OF WHITE-PINE STANDS.

OLD GROWTH.

A characteristic of the original white-pine forests which contributed largely to their commercial importance was their great age. The majority of the stands cut were from 200 to 300 years old. The trees in such stands were often from 150 to 200 feet high and from 4 to 7 feet in diameter, and produced lumber of the largest size, practically free from knots and other defects. In 1700, New Hampshire lumbermen were able to supply white-pine planks 25 feet long and 15 and 18 inches wide, and ship-dock material 36 feet long and 3 feet wide. In the Lake States single acres sometimes yielded 75,000 and occasionally 100,000 board feet, and entire "fortys" often averaged 50,000 feet per acre. Townships have been known to yield 400,000,000 board feet, or an average of about 18,000 feet per acre. Such yields were, of course, obtainable only where the forest was pure and practically unbroken, but even in rough country and in stands not exclusively of pine the large size of the individual trees often resulted in high yields.

White pine at one place or another associates with nearly every other tree species native to the Northeastern and Lake States. There are several species, however, with which it shows a special tendency to mix throughout its range or in portions of it. On the better soils hemlock, red spruce, sugar maple, beech, basswood, elm, and yellow birch form with white pine characteristic forest types. Hemlock is perhaps the most common associate throughout its range. Of slower growth, smaller size, and more shade enduring than white pine, it often forms a dense under-story of foliage beneath the pine crowns. Under the heavy shade of such stands the forest floor is absolutely bare, save for the thick layer of decomposing needles. In the early logging operations, which removed only the best of the pine, hemlock was considered valueless, except where tanbark markets existed, and was left standing. Even the felled trees from which bark had been removed were left to rot in the woods. With the disappearance of the pine, however, hemlock lumber has steadily increased in value.

On the deep, loamy soils where white pine associates with hemlock, maple, beech, and birch the white pine reaches its best individual development (Pl. I). Lumbermen early removed the white pine, and later in some places the hemlock from these stands, leaving the hardwoods in possession of the soil. Hemlock seedlings often persisted in the hardwood forest after the removal of the mature trees, but except in large openings the young white pine succumbed to the shade.

In the Northeastern States red spruce, which itself forms immense, practically pure stands, was also a common associate of white pine in the original mixed hardwood forest. Both spruce and pine have been largely culled, and while spruce seedlings are often abundant under the hardwood crowns, pine seedlings are rare. In aspen and paper birch stands, however, where the light foliage casts but little shade, young white pine and other conifers often grow in abundance, and eventually take the place of the short-lived birch and aspen.

On dry, sandy soils in the East, white pine often grows mixed with pitch pine, and in the West with Norway pine and jack pine. Both Norway and jack pine reach their best development in the Lake States and in Canada, where they form large pure stands on soils too dry for white pine, associating with the latter on slightly moister ones. The white and red pine mixture is especially important. Typical pine forests on fresh, sandy soils in Michigan consisted of white pine (45 to 55 per cent), red pine (25 to 45 per cent), with scattering hemlock (10 to 15 per cent), and occasional fir and hardwoods. Red-pine lumber is not much inferior to white pine, and large quantities are mixed with and marketed as the latter. Jack pine is so small and limby that until recent years it was considered valueless.

In the Southern Appalachians hemlock was the principal associate of white pine in the valleys, while on the drier slopes and ridges the latter usually grew in mixture with oaks, chestnut, and other hardwoods.

Throughout the early history of white-pine logging there was little demand for any except the finest grades of lumber, and the amount of loss involved in supplying these was enormous. Only the best logs from the best trees were taken, and of these as much as one-half was often lost in slabs. In fact, it was claimed that it took four trees to produce the amount of lumber contained in one. Labor was a very large, and stumpage value a very small, item in the cost of sawed lumber.

Even when this waste is considered, it is probable that the drain upon the forest by lumbering was less than half that involved through loss by fire. The dry, resinous slash of pine branches and leaves left after logging was almost sure sooner or later to become ignited. The hot fire from this not only consumed the scattering trees left on the cut-over areas, the seeds from which might have restocked the land with young growth, but also spread to adjoining timber. In this way countless acres were burned and reburned, until the ground was bare of mature timber, young growth, and even of the rich forest soil of decaying leaves and litter. Thus by destroying whatever seed trees and young growth lumbering had left, fire made it impossible for the forest to reproduce itself.

Though white pine often grew in places more valuable for agriculture than for the production of timber, the forest was removed from many situations either too steep and broken or too sandy and poor for agricultural use. The value for timber crops of such regions as the great sand plains of Michigan and the sandy areas of Wisconsin, and the mountains of Pennsylvania, is demonstrated by the quality of the white-pine stands which once grew there. With efficient protection from fire there is no reason why these regions can not again be made to produce pine.

SECOND GROWTH.

Stands which come up naturally after lumbering or fire are called second growth. In second-growth stands growth is vigorous, while in very old stands it is nearly if not quite balanced by decay. Overmature stands, being unproductive, represent idle capital, and the best use of the land demands their replacement with rapid-growing, productive stock. This, in fact, was what actually followed the logging of white-pine forests where fire did not later run over the ground. In Wisconsin there was estimated to be in 1897 about 200,000 acres of second-growth white-pine thickets which had sprung up in the previous 25 years.

In New England, where nearly all the original growth was removed many years ago, and where fires have as a rule been less destructive than in the Lake States, the lumber industry has already drawn heavily upon the second growth. Within recent years the cut of pine, which, in 1910, amounted to nearly 670,000,000 board feet, has been almost wholly of lumber from second-growth stands. This, of course, is much inferior to that from the original forests, chiefly because it is knottier, smaller, and has a larger proportion of sapwood; yet its usefulness for box boards and other purposes which do not demand large, clear stuff makes its aggregate value to New England but little below that of spruce. A large proportion of the young pine in New England has come in on abandoned farm lands, which in the aggregate embrace a very large area. These lands, which have proved themselves at least temporarily worthless for cultivation, are especially adapted to the growth of the tree. Cleared land, subsequently cultivated, presents ideal conditions for the germination of white-pine seed, and when a sufficient number of seed trees are near the area a dense, even-aged stand of white pine is almost sure to take possession of the ground. The growth of such stands is so rapid, their management so simple, and their yield under short rotations relatively so great that, for second growth, white pine is in many cases superior to any other species. A certain percentage of valuable hardwoods, such as white ash and black cherry, add considerably to the value of the stand, not only because of the high value of their wood, but also because when growing with them white pine produces clearer trunks, smaller branches, and is less likely to be damaged by weevils than when growing pure. Less valuable hardwoods, such as red maple, may serve a similar purpose. Gray birch, however, which in New England often associates with white pine, is distinctly undesirable in mixture with it. The slender stems of the birch, which commonly grow in clumps from a single stump, spread out widely, and when swayed by the wind are likely to damage the upper branches and tender tops of any small pines within their reach. Often a number of otherwise healthy young pines will be killed outright by a single clump of birches. (See Pl. III, fig. 2.)

SILVICAL CHARACTERISTICS.

Silvical characteristics embrace the soil, moisture, and light requirements of a species and its reproductive and growth characteristics.

SOIL AND MOISTURE REQUIREMENTS.

Broadly speaking, all the tree species in a given region require for their best growth much the same physical characteristics of the soil. In general, soils 3 or 4 feet deep, which are porous and well-drained but capable of holding sufficient moisture during dry seasons, are the best for all trees. Where the species differ is in their ability to thrive under less favorable conditions. In the North woods, for example, maple, beech, and hemlock need better soil conditions than white pine and do not thrive well enough on poorer soil to compete with it. White pine also grows best in deep, fresh, loamy soils, and the largest white pine trees were found scattered among the hardwood forests on such sites. The heavy shade cast by the broadleaf trees, together with their capacity, not shared by the pine, to sprout abundantly when cut or burned down, made it impossible for white pine to monopolize the best soils, and its forests were found, therefore, in drier and less fertile situations. Sand is the principal constituent of the soils on which grew the best white pine forests. The deeper, moister, and more loamy the sand the better are the trees developed. By its rapid growth on such soils the pine is able to exclude slower-growing species like hemlock, beech, and maple, and more light-needing trees like red, pitch, and jack pine. The last three species are less exacting than white pine, and will form forests on soils too dry for the latter. On the other hand, white pine is often found in poorly drained, somewhat swampy situations, in company with fir, arborvitæ, tamarack, and other swamp-inhabiting species. In such places, however, its growth is apt to be relatively slow.

Compared with the size of its trunk and crown, the root system of white pine is small. There is no taproot, but three or four stout roots grow downward slantingly, and in time give the tree a firm hold on the soil. On shallow soils with impervious hardpan or underlying rock strata the roots spread out close to the surface; in deeper soils they penetrate downward for 3 or 4 feet. Growth is less vigorous on shallow than on deep soils, because the former more quickly lose their moisture.

Tree leaves give up daily to the air great quantities of water, which the roots have absorbed from the soil. The more foliage a tree has the larger and more active must be its root system. Since the amount of light received by a tree directly influences the amount of its foliage, it must also influence the development of the roots. Thus, pine trees which grow in the open and have heavy foliage also possess deep and extensive root systems, while those in dense stands and with little foliage may have deep but rarely large or extensive roots.

LIGHT REQUIREMENT.

Light is the agency by which plant leaves manufacture food for the tree out of water drawn up through the roots and carbon dioxide obtained from the air. The amount of light necessary to sustain life, however, varies with different species. Compared with other trees, white pine may be classed as intermediate in its light requirement. It succumbs to shade much more quickly than hemlock, spruce, beech, or maple, but needs less light than red, pitch, or jack pine, gray birch, or aspen.

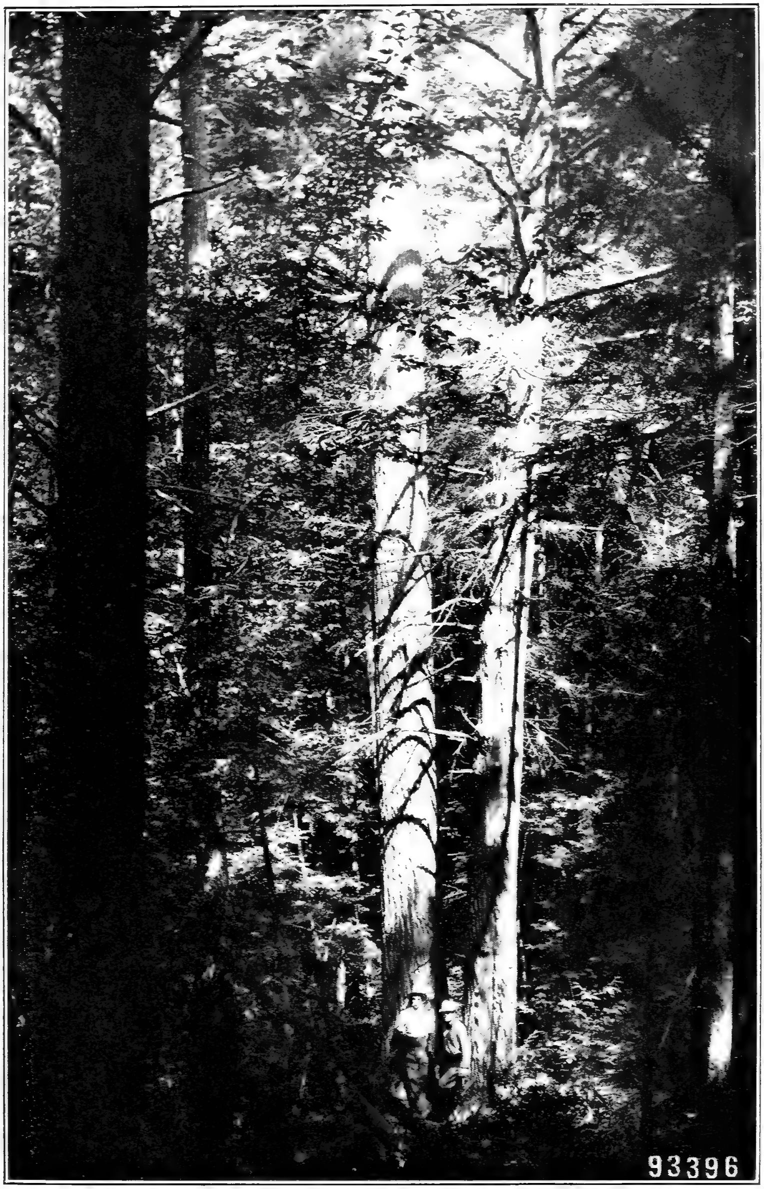
The less light a tree receives the slower will be its growth, and if shaded beyond a certain point it will die, practically from starvation. A suppressed tree to which light is admitted will respond in a greater or less degree, according to the length of time it has been suppressed, by putting forth new foliage and increasing its rate of growth. White pine does not possess the power to recover from suppression to the extent shown by hemlock, spruce, or fir, which will exist for years under heavy shade, and then, with the admission of light, spring at once into rapid, vigorous growth. If not too long suppressed, white pine will usually recover to some extent when released, though its subsequent growth is apt to be less thrifty than that of unsuppressed trees.

The trees more tolerant of shade naturally produce more foliage and themselves cast more shade than those less tolerant, and it is for this reason that white pine seedlings under maple, beech, hemlock, or even heavy white pine crowns, can not grow. Under the light shade of aspen, paper birch, or other intolerant trees young white pine often receives just enough light to keep it alive and to stimulate a rapid height growth, which results if the soil is good enough, in its eventually overtopping and displacing the other species. When mixed with heavy foliaged hardwoods or hemlock white pine crowns almost always project above the general level of the crown cover. In such stands the pine is able to reproduce itself only when its seeds fall in chance openings large enough to admit full light during the period necessary for the tops of the young trees to reach the level of the crown cover.

Since white pine is more tolerant of shade than is red pine it is able to grow in much denser pure stands and hence will produce a greater amount of wood per acre.

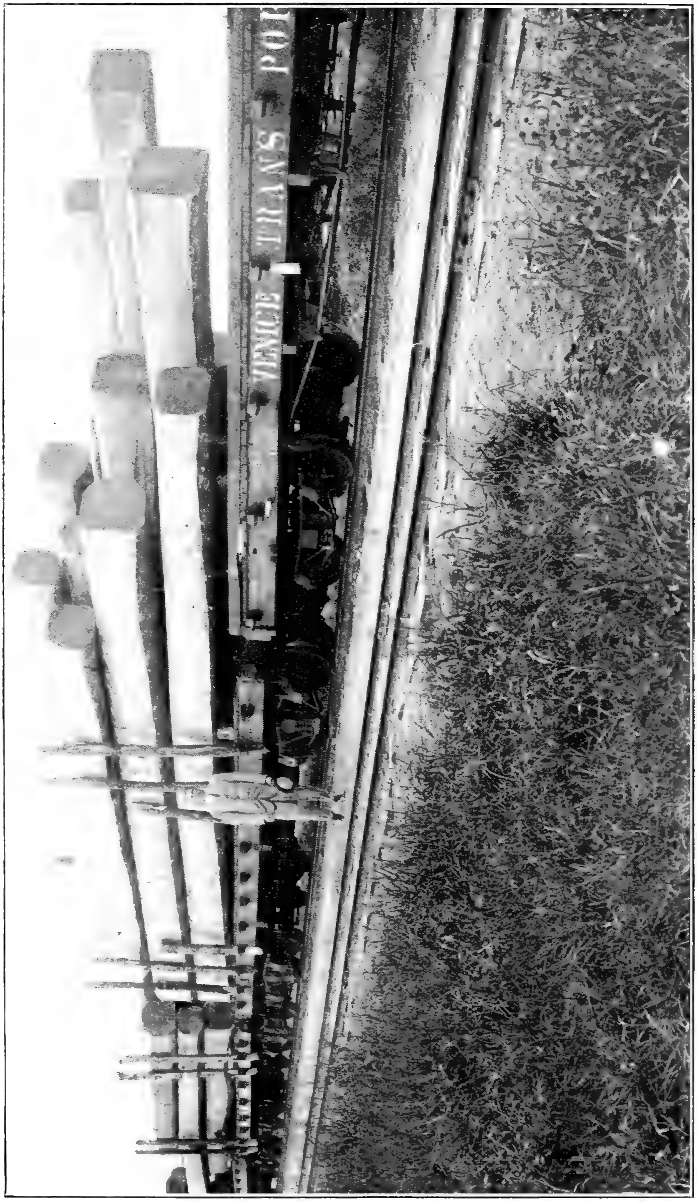
FORM.

Young white pines have a symmetrically conical form, due in large part to the fact that the branches grow in whorls. A whorl of branches marks each season's growth, so that two contiguous whorls afford a means of determining the height growth for a given year, and all the whorls together the approximate age of the tree. Each successive whorl shuts off light from the ones beneath, and these must increase in length if they are to continue to function. In the stand this increase is checked by the branches of adjacent trees, while in the open it is limited only by natural forces, chiefly gravity. In consequence, the crowns of open-grown trees are often broad pyramids reaching close to the ground.



A WHITE PINE TREE, PROBABLY 250 YEARS OLD, IN A VIRGIN FOREST OF THE HARDWOOD AND HEMLOCK TYPE.

[Note the clear, cylindrical trunk, as compared with the branchy, tapering stem of the adjacent dead hemlock.]



HEWED PINE TIMBERS FOR SHIPMENT TO ENGLAND.

[Two or three centuries are needed to produce timbers like these, the stumpage value of which is now $65 per thousand board feet. Menominee Indian Reservation.] (Photograph furnished by Mr. N. L. Dowling.)

In dense young stands most of the lower branches die from shade, growth is largely concentrated in the tops, and height growth is therefore rapid. Since the amount of food manufactured by the tree is proportionate to the amount of foliage, which in dense stands is small, wood is produced very slowly, and diameter growth is correspondingly slow. Thus while trees in the open are relatively short, with thick trunks and large, branching crowns, forest-grown trees are tall, with long, slender trunks (comparatively free from large branches if in mixture with hardwoods), and relatively short and narrow crowns. An open-grown tree actually contains more wood than a forest-grown tree of the same age, but its value, volume for volume, is much less. The difference lies not only in the better form of the forest-grown tree, but also in the actual structure of its wood, which contains more thick-walled mechanical tissue and less thin-walled water-conducting cells than that of open-grown trees.

In fully stocked sapling and pole stands, the stems are straight, slender, tapering, and smooth barked, with numerous whorls of small branches. At the end of this period the live crown is usually confined to the upper two-thirds of the stem. As the tree matures the bole becomes more cylindrical, and the crown loses its regularity and compactness. A characteristic defect of white pine, from a commercial standpoint, is its retention of dead branches, which causes the lumber to be knotty. In dense stands the branches, and consequently the knots they leave, are smaller than in the case of open-grown trees. Moreover, when in mixture with hardwoods, the slender dead branches are readily broken off by the swaying limbs of the broadleaf trees. The exceptionally clear boles of the virgin white pine which grew in dense hardwood forests were undoubtedly the result both of the shading and death of the branches while still small, and of the mechanical breakage of the small branches by the impact of spreading limbs of near-by trees. (See Pl. I.)

When white pine grows on the thin soils of ridges at high altitudes it produces a short and rapidly tapering trunk, while the crown, if exposed to severe winds, is likely to be distorted. One of the first considerations in planting white pine should be the quality of the site, since upon this depends the rate of growth and also, to some extent, the form which the trees will have.

The classification of trees according to the number of logs they will yield, practiced by timber estimators, illustrates the practical importance of form in determining the value of trees. Foresters have carried this still further, and on the basis of thousands of measurements of felled white pines have determined the average contents in board feet and cubic feet of trees of all the forms and sizes ordinarily found. Such figures are given in the volume tables (pp. 64–68).

REPRODUCTION.

Where it is planned to raise successive crops of trees, a comparative study of the methods of reproduction is important. The best and most economical means of reproduction are the natural ones afforded by the stand itself, provided these can be relied upon. Artificial methods are expensive, and require considerable technical skill in carrying them out. On the other hand, since they do not require the presence of trees to seed the area, a free choice of seasons and sites is possible. With plantations the element of uncertainty which surrounds natural reproduction is avoided.

The abundance and thrift of the second growth white pine on pastures and abandoned farms in the Northeast show that under proper conditions white pine can reproduce itself excellently by natural means.

SEED PRODUCTION.

The production of seed, like that of wood, depends upon the amount of food which the leaves manufacture. With other conditions equal, the more light a tree receives the earlier and more abundantly will it bear. Thus full-crowned, open-grown trees will begin to bear earlier and will produce more seed than small-crowned forest trees of the same age and on the same kind of soil. Seed production is also earlier and more abundant on good soils than on poor. With plenty of light, white-pine saplings begin to bear cones when less than 20 years old. As a rule, however, seed are not produced in abundance until the trees are from 35 to 70 years old, depending upon the amount of light received. As the trees increase in age they bear more prolifically, and the proportion of fertile seeds increases. With the decline in vigor which attends old age there is probably a corresponding decline in the amount and quality of seed produced, but white pine continues to bear fertile seed in abundance for at least 200, and probably 300, years.

White pine cones require two years to mature. They begin to form in June, and by the fall of the first year reach a length of 1 or 2 inches. Thus it is possible to tell a year in advance whether or not there will be a heavy seed crop. The cones reach their full length—5 to 11 inches—early in the summer of the second year, and open in the fall, usually in September. A frost sufficiently severe to kill squash vines will often cause mature cones to open. Each cone bears from 50 to 75 oval seeds—two on the upper face of each scale—about one-fourth of an inch long, and equipped with thin, membranous wings. A bushel of cones will yield from one-half pound to a pound of cleaned seeds, which run from 26,000 to 30,000 to the pound.

Heavy crops of seed are borne at intervals of from 3 to 7 years, with occasional intervening years of lighter production. The same year may not mark a heavy seed production over the entire range of white pine, and a "seed year" may occur in some localities simultaneously with an "off year" in others. Local conditions of soil and climate have great influence on the frequency of seed years. Scarcity of water stimulates seed production in most plants, and it is quite possible that fluctuations in soil moisture may have some influence on the frequency of seed years of white pine.[1] In off years not only is less seed produced, but the ravages made upon the supply by birds and rodents is more keenly felt. Insect damage, too, is concentrated, so that a small crop is likely to be one of low quality as well. Even in off years, however, seed production in some localities may be fairly plentiful.

The relatively long intervals between seed years put white pine at a disadvantage, compared with trees which bear heavy crops more frequently. Several of the broadleaf species bear seed abundantly each year, and when these are shade-enduring trees with heavy crowns they are often able, in company with underbrush, completely to cover a cleared area, and so prevent white pine from obtaining a foothold. In the Lake States, jack pine, which nearly every year bears abundant crops of small, winged, fertile seed, is able to monopolize cleared areas, practically to the exclusion of white pine.

Seed Distribution.

The chief agent of distribution of white pine seed is wind. Trees standing on high, windy slopes and ridges may shed their seeds to a distance of half a mile, or even more, over the adjoining lowland. In valleys the range of seeding is very much less. On level land the distance to which seeds will be carried in any number, when unobstructed by crowns of other trees, is usually between 100 and 200 feet. Reproduction, of course, is densest and most even-aged near the mother trees. Where abandoned fields or pastures adjoin white pine woodland, dense even-aged stands of pine are almost sure to develop, the stand becoming more open as its distance from the seed supply increases. When seed trees are left well distributed on a cut-over area, a fully stocked, even-aged second growth may often be established after one or two full seed years (Pl. IV, fig. 2). When seed trees are scarce or poorly distributed, complete restocking may require a much longer time, or the result may be that other species, possibly undesirable ones, will come in with the pine. From 5 to 10 good seed trees per acre are usually sufficient to give a close, even-aged stand of second growth. The number should never be less than 3 or 4, selected with reference to the direction of the prevailing wind.

---

[1] Height and Dominance of the Douglas Fir, by T. C. Fry. Forestry Quarterly, vol. 8, No. 4, p. 467.

Germination of Seed and Growth of Seedlings.

When fresh, from 70 to 90 per cent of white-pine seeds are fertile, and under favorable conditions will germinate. With unfavorable conditions, however, the mortality is very great. Much of the seed, either while in the cone or after it falls to the ground, is consumed by birds and rodents. Of the seeds which escape destruction by animals, many die through falling on unfavorable sites. After germination seeds need, for example, a certain amount of moisture, though too much will cause them to decay. Seeds which fall during dry seasons may lie dormant until the next year, provided they are not destroyed in the meantime. When properly stored, white-pine seeds can be kept for five years or more without great loss, but under natural conditions it is probable that only a very small proportion ever germinate after the second spring following their ripening. Quantities of pine seed are destroyed by forest fires, which may burn the cones on the trees or destroy the seed after it has fallen. When drought and forest fires follow the falling of seed during an off year, nearly the whole of the crop may be lost.

Germination takes place, as a rule, in the spring, and in practically every kind of soil with sufficient heat and moisture. If the young seedling is to live, its roots must soon find the mineral soil. Young plants which spring up on insufficiently decomposed leaf litter are almost sure to die.

Seedlings thrive in soil which is at once moist, porous, and well drained. Sandy or loamy soils, well mixed with decayed organic matter, and protected by vegetation or leaf litter, meet these requirements. Should the soil dry out even to the slight depth to which the roots of the seedlings have penetrated, a great many of the young trees will die.

To determine the effect of moisture conditions upon the death rate of seedlings during the first two years of life, nine sample plots were marked out in 1909 near Petersham, Mass., in dry, fresh to moist, and wet situations. The dry situations were either entirely unshaded or only partially shaded by underbrush, and had from 2 to 3 inches of pine or else from 4 to 5 inches of broadleaf litter. The fresh to moist situations were well drained, lightly shaded, some bare of pine litter, and others with a cover up to 3 inches in depth. The wet situations were low, poorly drained bottom lands on which water stood during a part of the spring. The average number of seedlings on the plots in 1909 was: In the dry situations 29, in the fresh to moist 60, and in the wet 14. When counted in 1910 the proportion still alive in the dry situations was 53 per cent, and in the fresh to moist 86 per cent, while in the wet none had survived.

As long as the young roots extend but a few inches into the ground the character of the subsoil makes little difference; but as the roots

FIG. 1.—WHITE PINE PRUNES ITSELF POORLY WHEN GROWN IN PURE STANDS.

FIG. 2.—WHITE PINE SAPLINGS ENDANGERED BY GRAY BIRCH AND IN NEED OF A DISENGAGEMENT CUTTING.

FIG. 1.—A 60-YEAR-OLD WHITE PINE STAND IN WHICH A REPRODUCTION CUTTING WAS MADE THREE YEARS AGO.

[This resulted in an abundant reproduction of both white pine and white ash. Because of its slow growth when very young the pine has little chance of success in competition with the ash, and the latter should be favored.]

FIG. 2.—WHITE PINE REPRODUCTION, FILLING A CUT-OVER AND BURNED SPACE IN A HARDWOOD FOREST.

[Pine seed trees in the background.]

penetrate into it the subsoil becomes more and more important in the growth of the tree. Its roots once well established in fertile, moist soil, future growth of the seedling depends very largely upon the character of the vegetation surrounding it. In hot, exposed situations it needs, during the first summer, a slight protection from the intense heat and light of the sun. On old fields and pastures this is afforded by short grasses and low scattered herbaceous vegetation, like sweet fern and blueberry. A light cover of ferns or other small herbs will often cast just enough shade to protect the pine seedling, yet afford it sufficient sunlight with which to manufacture food.[1] On the other hand, white-pine seedlings grow so slowly during the first four or five years that they are very easily killed by tall, dense, vegetation of any kind, such as berry bushes, golden rod, fireweed, fern brakes, or rank wild grasses. Not only does such vegetation keep out needed light, but its roots take from the soil the moisture which the young white pine requires. Under the protection of young, fast-growing hardwood sprouts, witch hazel, dogwood, and similar undergrowth, white-pine seedlings may thrive for a year or two, but the shade of such stands is usually too dense for continued growth of the pine (see Pl. III, fig. 2, and Pl. IV, fig. 1). In stands containing broad-leaf trees many white-pine seedlings are smothered by fallen leaves.

To determine the influence of different degrees of shade upon the vitality and rate of growth of white-pine seedlings a number of sample plots were laid out in 1905 at Keene, N. H., in stands of different crown density, but in other respects alike. Table 1, based on counts in 10 plots of 1 square rod each, shows the average size and number of seedlings per square rod in 1905 and the number and size of those still alive in 1909.

TABLE 1.—*Vitality and rate of growth of seedlings under different degrees of shade.*

Crown cover.	Average number of seedlings per square rod.		Per cent living.	Average height.		Average growth in 4 years of seedlings which survived.
	1905	1909	1909	1905	1909	
				Inches.	*Inches.*	*Inches.*
Dense	271	15	5.5	1.5	4.5	3.0
Broken	102	62	60.8	1.5	10.0	8.5
Open	100	94	94.0	1.5	11.0	9.5

GROWTH OF INDIVIDUAL TREES.

An important characteristic of white pine is that its growth is steady and uniform up to an advanced age. In this it differs from all the other eastern and many of the western pines, in which the rate

[1] Influence of Shade and Other Factors on Plantations, by G. W. Kimball and E. E. Carter. Forestry Quarterly, Vol. 11, No. 2, p. 176.

of growth decreases rather abruptly when the tree is still far from decadence. Red pine, for example, has a fairly uniform and rapid growth until about 100 years old, when a marked falling off occurs, the tree growing at a slower rate until its death 100 or 200 years later. Jack pine exhibits a similar trait, though its period of rapid growth ceases very much earlier than that of red pine. It is this habit of sustained growth which gives white pine its great size as compared with the two other species.

The rate of growth varies with the age of the tree, the amount of light received, and the fertility of the soil in which it grows. In general, growth is more rapid on good soils than on poor, and in youth than in old age. The period during which growth is most rapid comes earlier when the tree is favorably situated than when it grows on poor soil.

Growth in Height.

White-pine seedlings grow very slowly, and few of them reach a height of more than a foot during the first 5 years. For the first 3 years annual growth is little more than an inch. Thus 1, 2, and even 3 year old seedlings are so inconspicuous that they are likely to be overlooked, especially when among grass or weeds. During the following two seasons, when rapid growth commences, the top shoots of the seedlings appear everywhere, giving the impression that they have sprung up in a single year.

The height growth of seedlings for the first 10 years under average conditions is shown in Table 2. In a nursery or under specially favorable circumstances the rate of growth may be much faster, while under partial shade it will be slower.

Table 2.—*Height growth of white-pine seedlings.*[1]

Age.	Height.	Age.	Height.
Years.	*Inches.*	*Years.*	*Inches.*
1	1.0	6	17.0
2	1.5	7	24.0
3	3.5	8	32.0
4	7.0	9	45.0
5	11.0	10	64.0

On good, moist soils height growth is most rapid at about the fifteenth year, when it often exceeds 3 feet annually. On poor, dry soils, however, the maximum may not occur before the fortieth year, and then not equal the growth on good soil. From the time when the growth culminates its rate gradually decreases until toward the end of the second hundred years it amounts to only 2 or 3 inches per year.

[1] From measurements of 1,600 young trees. Table from "Natural Replacement of White Pine on Old Fields in New England," by S. N. Spring.

Height growth is also influenced by the amount of light which the tree receives. It is most rapid when the upper part of the crown alone receives a full supply. In open-grown trees, which receive light from all sides, the growth energy is distributed over many large branches, and height growth culminates early, so that the tree remains relatively short, stout, and branchy. On the other hand, if the trees grow so closely together that the crowns are small and crowded, the rate of growth will again be slow.

It is thus evident that trees of the same age and growing in the same situations may vary somewhat in the rate of growth, according to their nearness to one another. This difference, however, is much less than that caused by a marked difference in the quality of the soil. Height growth is, in fact, commonly considered the most reliable single indication of site quality.

Since ordinarily only one whorl of branches is produced in a single year, the age of young to moderately old trees can usually be determined roughly by counting the number of whorls or the scars left by them. When these are absent close to the ground it is necessary to estimate the period which the tree required to grow to the height of the first visible whorl. For rough age determination it will usually do to assume that it took 10 years to reach breast height.

Growth in Diameter.

Growth in diameter takes place through the formation of the thin, concentric layers of wood, commonly called annual rings. With very rare exceptions only a single ring is formed each year, so that the number and width of the rings are a safe guide in determining the age and rate of growth of the tree. To determine the precise age it would be necessary to cut the tree at or within an inch of the surface of the ground, since only in this way can the first year's growth be included. Naturally, the further up the tree the section is cut, the less will be the number of rings, and the amount of this difference is the number of years it has taken the tree to reach the height of the cross section. It is customary to express growth in terms of the diameter breasthigh, since on standing trees this is the point at which the diameter is usually measured.

Like growth in height, the diameter growth of white pine reaches its maximum early in life, and then slowly decreases. It is more persistent than the height growth, however, and continues at a moderate rate long after the former has practically ceased. Trees 60 or 70 years old may still be growing fairly rapidly in diameter.

Diameter growth is slowest when the light supply is barely sufficient to keep the tree alive, and most rapid when the tree grows with its crown in full light and produces a heavy foliage. On dry soils or where there is deficient air moisture diameter growth, like height growth, is slow. This is true also of swampy soils.

Growth in Volume.

Growth in volume is the product of growth in both height and diameter, and is influenced, moreover, by the shape of the tree. In white pine its rate becomes rapid after the period of rapid height growth has passed, and persists to an advanced age, gradually becoming less, until in old age it is more than offset by decay. Like that of diameter growth, the rate is more rapid in the case of open-grown trees with large crowns than in forest trees with small crowns, though, as previously mentioned, the wood produced is less valuable.

Along with the growth in volume there proceeds an increase in quality. This takes place partly through the mere increase in the size of the lumber which can be sawed out and partly through the increase in freedom from knots. White pine holds its branches so tenaciously, however, that, unless pruned, little freedom from knots can be expected before the fiftieth year. The quality of the timber is further improved by the conversion of the soft sapwood into heartwood, which goes on somewhat irregularly as the diameter increases.

GROWTH OF STANDS.

The development of a white-pine stand is a continued struggle between the trees for light and growing space. This struggle commences when the branch tips of the seedlings begin to touch and interfere with each other, and is most acute during the early period of rapid height growth. Success of individual trees in the competition is determined by their ability to make rapid height growth, and so to keep their crowns in the light. As the less vigorous trees fall behind, they become more and more shaded by their thriftier neighbors, and finally die. The mortality from crown competition gradually decreases from the early period of vigorous growth, until at the time the trees have reached full size it is very small. The decrease in the number of trees, however, is more than made up by the size of the survivors. This is shown in Tables 3 to 5, where, even when the decrease in the number of trees is most rapid, the aggregate basal area, breast high, and volume per acre continue to increase—rapidly in first-quality and slowly in third-quality stands.

The difference in height and crown vigor which this struggle brings about makes it possible to classify the trees of a stand in the following way: (1) *dominant* trees, which have full and vigorous crowns and in general overtop their neighbors; (2) *codominant,* those with narrower crowns, which are beginning to fall behind the dominant trees in height growth; (3) *intermediate,* shorter trees, closely crowded by their neighbors and receiving light only from above; (4) *suppressed* trees, those which are shaded from above as well as from the sides, and which will soon die; (5) *dead,* trees which have finally succumbed to shade.

The rate of growth of the stand is influenced by the same physical factors which control that of the individual tree. Computations of future yield must, therefore, take into account conditions under which the trees grow, and it is customary to classify stands according to their height growth, which, as previously said, is the best indicaton of the quality of the site. Quality I shows the most rapid growth, and quality III the slowest.

Stands fully stocked, that is, those which contain just enough trees to utilize all the growing space and to produce well-formed trunks, are said to be "normal." Too many trees result in slender-stemmed, slow-growing stands; too few do not fully utilize the growing space, and produce limby stands of relatively low value. Since growth is more rapid and competition more keen in good situations than in poor ones, the number of trees is less and their size greater in fully stocked quality I stands than in quality III stands of the same age and type.

YIELD OF SECOND-GROWTH WHITE PINE.

The yield of a stand, that is, the amount of wood produced per acre, in large measure determines the choice of species or of material to be produced, the length of rotation, and other important features of management. Volume growth of a stand depends, of course, upon the height, diameter, and volume of the individual trees, and also upon the number of trees.

Tables 3 to 6, which give the yield per acre of three qualities of second-growth white pine, are based upon the results of measurements of 196 typical fully stocked second-growth stands in New Hampshire, by C. A. Lyford and Louis Margolin of the Forest Service.[1] The tables are for use either as guides in predicting the future yield of young second-growth or for determining the present yield of existing stands.

TABLE 3.—*Yield per acre in cubic feet, quality I.*

Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.	Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.
Years.	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*	*Years.*	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*
10	7.2	1.7	1,728	29	800	60	85.5	12.8	311	278	10,500
15	14.5	2.9	1,520	68	1,400	65	90.5	13.7	279	286	11,300
20	24.5	4.0	1,322	115	2,100	70	94.5	14.7	249	293	11,900
25	34.5	5.2	1,115	162	3,000	75	98.0	15.6	226	300	12,500
30	44.0	6.4	879	196	4,000	80	101.5	16.5	207	307	13,000
35	53.0	7.5	710	218	5,200	85	105.0	17.4	190	313	13,500
40	61.0	8.6	583	235	6,500	90	108.0	18.2	177	319	14,000
45	68.0	9.7	485	249	7,700	95	110.5	19.0	165	324	14,400
50	74.5	10.8	408	260	8,800	100	113.0	19.8	154	330	14,700
55	80.5	11.8	354	269	9,700						

[1] Tables based on these measurements have already been published in the biennial reports of the Forestry Commission of New Hampshire for 1905–6 and 1907–8. The present tables differ from the others in that the separation into quality classes is made upon the basis of the height of the dominant trees instead of that of the yield itself.

TABLE 4.—*Yield per acre in cubic feet, quality II.*

Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.	Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.
Years.	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*	*Years.*	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*
10	6.0	1.4	2,015	20	650	60	74.5	10.7	397	248	8,500
15	12.0	2.2	1,834	50	1,150	65	79.0	11.6	348	255	9,200
20	19.5	3.2	1,626	90	1,750	70	83.0	12.4	311	261	9,840
25	28.0	4.1	1,420	131	2,420	75	86.5	13.3	277	267	10,400
30	36.5	5.1	1,192	169	3,250	80	90.0	14.1	251	272	10,930
35	44.5	6.1	950	193	4,180	85	93.0	14.9	229	277	11,400
40	51.5	7.1	760	209	5,130	90	95.5	15.7	210	282	11,850
45	58.0	8.0	633	221	6,100	95	98.0	16.4	195	286	12,250
50	64.0	8.9	537	232	7,000	100	100.0	17.1	182	290	12,630
55	69.5	9.8	460	241	7,800						

TABLE 5.—*Yield per acre in cubic feet, quality III.*

Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.	Age.	Average height of dominant trees.	Diameter breast high of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.
Years.	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*	*Years.*	*Feet.*	*Inches.*		*Sq. ft.*	*Cu. ft.*
10	4.0	1.0	2,408	14	530	60	64.0	8.6	543	219	6,530
15	9.0	1.6	2,234	33	900	65	68.0	9.4	465	224	7,160
20	14.5	2.3	2,060	60	1,350	70	71.5	10.1	412	229	7,760
25	21.0	3.1	1,886	98	1,850	75	75.0	10.9	361	234	8,320
30	28.5	3.9	1,676	139	2,450	80	78.0	11.7	318	238	8,820
35	36.0	4.7	1,400	167	3,100	85	81.0	12.4	288	242	9,300
40	42.5	5.5	1,118	183	3,780	90	83.0	13.2	258	245	9,750
45	48.5	6.3	900	194	4,500	95	85.5	13.8	239	248	10,150
50	54.0	7.0	764	204	5,200	100	87.0	14.5	219	251	10,530
55	58.0	7.8	639	212	5,870						

Although only fully stocked stands were selected as a basis for the tables, the field data were further narrowed by choosing only those which came nearest to the average degree of stocking. As a means of making the selection the total basal area per acre of the sample plots—that is, the aggregate cross-section area at breast height of all the trees, expressed in square feet—were plotted on cross-section paper according to age and quality and an average curve drawn through the points representing each quality class. All the sample plots in each class which deviated from the average by more than 10 per cent were considered abnormally stocked. Cubic-foot yields given in the tables were computed by means of Table 26, Appendix.

The lumber yields given in Table 6 are the graphical averages of the individual sample plot yields obtained by means of the board-foot volume table 24 on page 66, which is based on the actual saw cut. All trees over 5 inches breast high were scaled.

TABLE 6.—*Yield per acre in lumber of even-aged second-growth white-pine stands.*

Age.	Lumber yield per acre.			Age.	Lumber yield per acre.		
	Quality I.	Quality II.	Quality III.		Quality I.	Quality II.	Quality III.
Years.	*Board ft.*	*Board ft.*	*Board ft.*	*Years.*	*Board ft.*	*Board ft.*	*Board ft.*
20	4,500	....	....	65	65,100	51,600	38,100
25	8,400	5,400	....	70	69,900	56,100	42,300
30	13,900	9,600	5,300	75	74,100	60,200	46,300
35	22,500	15,900	9,300	80	77,850	64,000	50,100
40	32,800	23,500	14,200	85	81,400	67,500	53,700
45	41,800	30,600	19,200	90	84,800	70,900	57,000
50	49,100	36,600	24,100	95	88,000	74,000	60,000
55	55,000	42,000	29,000	100	91,200	77,000	62,800
60	60,200	46,900	33,600				

In using the yield tables it should be borne in mind that, since they are based upon fully stocked stands, they represent better conditions than usually exist in natural stands except over small areas. For this reason, and also to allow for crooked and defective trees, it is advisable to discount the values given by an amount suggested by the conditions in each individual case. A discount of from 10 to 15 per cent of the board-foot yield will usually be ample.

The rate at which average stands increase in volume may be easily determined from the yield tables by dividing the yield at any desired age by the number of years. The average annual growth thus obtained is of use in comparing the rate of growth of stands of different ages or in contrasting the growth of stands of the same age but in different qualities of site. Table 7 gives the average annual growth in cubic and board feet at 5-year intervals for average stands of three qualities. The point where growth culminates (indicated in the table by heavy figures) in general occurs earliest in the best sites. Therefore to secure continuously the greatest yield from successive crops of white pine, the final cutting would have to be made at an age when the average annual growth is greatest. That this age does not always coincide with that at which the money income is greatest is brought out under "Rotation," page 36.

TABLE 7.—*Average annual growth per acre, by quality classes.*

Age.	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.
Years.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Board ft.*	*Board ft.*	*Board ft.*
10	78	65	53	....	....	....
15	93	77	60	....	....	....
20	108	88	68	225	....	....
25	120	97	74	336	216	....
30	135	108	82	463	320	177
35	150	119	89	643	455	266
40	163	128	95	820	588	355
45	171	136	100	929	680	427
50	176	140	104	982	732	482
55	**176.4**	**141.8**	107	1,000	764	527
60	175.8	141.7	109	**1,003**	782	560
65	173	141.5	110.1	1,002	794	586
70	170	140.6	110.8	999	801	604
75	167	139	**110.9**	988	**803**	617
80	163	137	110.3	973	800	626
85	159	134	109.4	958	794	632
90	155	132	108	942	788	**633**
95	151	129	107	926	779	632
100	147	126	105	912	770	628

SECOND-GROWTH WHITE PINE AS AN INVESTMENT.

With the market and labor conditions now prevailing in New England and elsewhere within the range of white pine, second-growth stands, when properly managed, should yield a relatively high rate of interest. In this chapter the factors which bear upon the success of investments in second-growth white pine will be taken up separately, and their combined effect considered when returns at different rates of interest are desired. The values and costs used are based on a careful study of actual conditions in New England.

Two things determine the profit or loss from investments in second-growth white pine: (1) The gross returns from the financially mature stand, here regarded as the stumpage value, and (2) the total cost of raising white-pine stands at compound interest to the end of the rotation. Strictly speaking, the gross returns would be the price received for the lumber delivered, but, since stands are ordinarily valued in terms of the standing timber, stumpage value can be considered the gross returns. If the total cost of production equals the gross returns, the investment is a success. If the gross returns exceed the cost, the excess represents either a higher rate of interest than anticipated or a clear profit at the original interest rate. If the cost exceeds the stumpage value, the investment at the original rate of interest has been unsuccessful, although at a lower rate it *may* have yielded a profit.

GROSS RETURNS.

The value of standing timber is the difference between the market value of the finished product and the total cost of cutting, manufacture, and delivery, including the operator's profit on his investment.

Market Value of Lumber.

The chief product of second-growth pine stands, as already mentioned, is round-edged box board lumber and match stock. In most second-growth stands the lumber yield consists of two grades, both round-edged: One-inch box boards or siding, worth from $12 to $15 per thousand board feet, and 1⅝ to 2⅛ inch box boards and match lumber, worth from $17 to $18 per thousand. In addition, there may also be a small amount of sash and blind stock, worth from $30 to $35 per thousand. As the trees increase in size larger and consequently more valuable lumber can be had, and the proportion of 1-inch siding diminishes. Thus, lumber from logs 5 inches in diameter at the small end is made up of from 17 to 25 per cent of 1-inch siding, while in 10-inch logs the proportion is less than 8 per cent, and in logs over 18 inches at the small end it is negligible. The increase in value of the lumber from second-growth stands up to 70 years of age is shown in Table 8.[1] The values per thousand board feet are based on the values and the approximate proportion of the various grades just mentioned. From the values per thousand board feet and the board foot yields given in Table 6, values per acre were obtained. The figures given in Table 8 are the approximate values of the manufactured lumber delivered at the local market, and should not be mistaken for stumpage values, which are these values minus all costs of exploitation.

Table 8.—*Value f. o. b. local markets of lumber from second-growth pine stands of various ages and qualities.*

Age.	Value.					
	Quality I.		Quality II.		Quality III.	
	Per thousand board feet.	Per acre.	Per thousand board feet.	Per acre.	Per thousand board feet.	Per acre.
Years.						
20	$13.00	$58.50	....	....	....	....
25	14.50	121.80	$13.00	$70.20	....	....
30	16.20	225.18	14.50	139.20	$13.00	$68.90
35	17.30	389.25	16.20	257.58	14.50	134.85
40	17.80	583.84	17.30	406.55	16.20	230.04
45	18.00	752.40	17.80	544.68	17.30	332.16
50	18.20	893.62	18.00	658.80	17.80	428.98
55	18.30	1,006.50	18.20	764.40	18.00	522.00
60	18.40	1,107.68	18.30	858.27	18.20	611.52
65	18.50	1,204.35	18.40	949.44	18.30	697.23
70	18.60	1,300.14	18.50	1,037.85	18.40	778.32

[1] There is reason to believe that by an early pruning and subsequent thinnings these values can be greatly increased for rotations of from 50 to 70 years.

LOGGING COSTS.

Most of the second-growth pine is sawed by portable mills of 10,000 or 15,000 board-feet capacity. These can be moved cheaply from place to place, and a stand of 100,000 board feet usually warrants a set-up. The different parts of the lumbering operation vary somewhat in cost, but in New England, with a 9-hour day, would average about as follows per thousand board feet:

Cutting	$1.25
Skidding	2.25
Sawing and piling at mill	3.25

Insurance at the rate of 1½ per cent per year, or at a less rate for portions of a year, and interest on the logging investment, add to the cost about 25 cents per thousand board feet, and raise the average total cost, exclusive of hauling, to about $7 per thousand. This figure is used in deriving the succeeding tables for stumpage values and profit and loss. The cost would tend to be greater for small and less for large timber. Usually the lumber is air-dried at the mill for from 3 to 6 months after being sawed. Cutting is ordinarily done in the winter, sawing in the early spring, and hauling in August, after the haying season, when teams are available.

On level roads in average condition a good team can haul from 1,500 to 2,200 (average 1,800) board feet of air-seasoned 2⅛-inch white-pine lumber to the wagonload. In many localities a distance from market of from 5 to 11 miles is considered a "one turn" haul. For shorter distances the tendency is to increase the loads and rest the horses oftener, while for long hauls the load might be reduced to 1,200 or 1,300 board feet. A single-horse wagonload usually contains from 700 to 900 board feet.

Hauling from the mill to the market is usually done under contract at either so much per day or at so much per thousand board feet. It is the most variable of the logging costs, since it depends upon the length of the haul, the character of the roads and topography, the wages paid for team and driver, and the amount of lumber that can be hauled at one load. It is, therefore, convenient to determine the cost of hauling in terms of the amount of lumber that can be hauled per day at a given wage rate. Five dollars per day is perhaps the most common rate for team and teamster throughout the northeast.[1] This rate is used in Table 9, which shows the cost of hauling and the total cost of logging for different amounts of lumber hauled per day by each team.

[1] The influence of different wage rates from $4 to $5.50 on the cost of logging and the stumpage value is discussed in Forest Service Bulletin 96, pages 20–29.

TABLE 9.—*Cost of hauling and total cost of logging per thousand board feet, for daily hauls per team of 1,000–4,000 board feet of lumber.*

Daily haul.	Hauling cost, with wage rate of $5 per day, per thousand board feet.	Total cost of logging, including hauling, per thousand board feet.
Board feet.		
1,000	$5.00	$12.00
2,000	2.50	9.50
3,000	1.67	8.67
4,000	1.25	8.25

The total cost per acre of logging average second-growth stands, based on the total cost per thousand in Table 9 and the yields given in Table 6, are shown in Table 10.

TABLE 10.—*Total cost per acre of logging and hauling, for stands of different ages and qualities, and for daily hauls, per team, of 1,000–4,000 board feet of lumber.*

[Based on yields given in Table 6, and costs per thousand board feet from Table 9.]

Age.	Daily haul, per team, 1,000 board feet.			Daily haul, per team, 2,000 board feet.			Daily haul, per team, 3,000 board feet.			Daily haul, per team, 4,000 board feet.		
	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.
Yrs.												
20	$54.00	....	....	$42.80	....	....	$39.00	....	....	$37.10	....	....
25	100.80	$64.80	....	79.80	$51.30	....	72.80	$46.80	....	69.30	$44.50	....
30	166.80	115.20	$63.60	132.00	91.20	$50.40	120.50	83.20	$46.00	114.70	79.20	$43.70
35	270.00	190.80	111.60	213.80	151.00	88.40	195.10	137.90	80.60	185.60	131.20	76.70
40	393.60	282.00	170.40	311.60	223.30	134.90	284.40	203.80	123.10	270.60	193.90	117.20
45	501.60	367.20	230.40	397.10	290.70	182.40	362.40	265.30	166.50	344.90	252.50	158.40
50	589.20	439.20	289.20	466.50	347.70	229.00	425.70	317.30	209.00	405.10	302.00	198.80
55	660.00	504.00	348.00	522.50	399.00	275.50	476.90	364.10	251.40	453.80	346.50	239.30
60	722.40	562.80	403.20	571.90	445.50	319.20	521.90	406.60	291.30	496.70	387.00	277.20
65	781.20	619.20	457.20	618.50	490.20	362.00	564.40	447.40	330.30	537.10	425.70	314.30
70	838.80	673.20	507.60	664.00	533.00	401.90	606.00	486.40	366.70	576.70	462.80	349.00

NOTE—The costs in Table 10 are based on an assumed average for all ages. As a matter of fact, since it costs more to log small than large timber, the logging cost (exclusive of hauling) would decrease slightly with the age of the stand.

OPERATOR'S PROFIT.

In computing stumpage value there should be deducted from the market value of the lumber not only the logging costs but also the amount of profit which an operator who bought the timber could be expected to demand on his investment. The profit represents the legitimate income upon the money invested, both in the standing timber itself and in the cutting, manufacture, and delivery at the local market of the lumber. The rate of this profit would be fixed largely by such considerations as the length of time the timber must be held before being cut, the rate of interest, risk, depreciation of equipment, and proportion of the time it is in use, competition, etc. In general, a profit of 10 per cent over and above all logging costs is probably warranted in most regions where there is a fairly continuous employment for the sawmill equipment, and this rate of profit has been used in deriving the stumpage values in Table 11.[1]

A 10 per cent profit on an investment in stumpage and logging amounts to one-eleventh of the market value of the lumber.[2] For second-growth pine lumber at the market values given in Table 8, the profit can therefore be obtained by dividing each value by 11. The profit per acre will be based on the average yields per acre given in Table 6. At 15, 20, 25, and 30 per cent this is, respectively, three-twenty-thirds, one-sixth, one-fifth, and three-thirteenths of the market value.

Stumpage Value.

Stumpage values per thousand board feet and per acre (based on the board-foot yields in Table 6) are given in Table 11. These were obtained by deducting the logging costs per acre (Table 10) and a 10 per cent profit on the combined stumpage and logging investment from the market values per acre given in Table 8.[2] They apply, for each quality, to stands of average yield, provided the market values and logging costs are identical with those used in this bulletin. The yield of individual stands may differ somewhat from the averages given, while the values and costs will, in all likelihood, vary with the locality. Where these are radically different the stumpage value is best found by means of the formula.

---

[1] The effect on stumpage values of a 20 per cent profit is discussed in Forest Service Bulletin 96, pp. 24–29.

[2] In computing the stumpage values the formula $S=\frac{M}{1.0P}-C$ was used, in which S=stumpage value. M=market value, C=logging costs, and P=rate of profit on the combined investment in stumpage and logging. For different rates of profit this reduces to the following forms:

For a profit of 10 per cent: $S=\frac{10}{11}M-C$

15 per cent: $S=\frac{20}{23}M-C$

20 per cent: $S=\frac{5}{6}M-C$

25 per cent: $S=\frac{4}{5}M-C$

30 per cent: $S=\frac{10}{13}M-C$

To determine the stumpage value obtainable, if any desired rate of profit is to be secured, the logging costs should therefore be deducted from the corresponding fraction of the market value.

TABLE 11.—*Stumpage values per thousand board feet and per acre of second-growth white-pine stands of average yield.*[1]

Age.	Quality.	Stumpage value, with hauling capacity, per team, of— 1 M per day.		2 M per day.		3 M per day.		4 M per day.	
		Per M.	Per acre.	Per M.	Per acre.	Per M.	Per acre.	Per M.	Per acre.
Years.									
20	I	....	....	$2.32	$10.50	$3.15	$14.00	$3.57	$16.00
	II	....	....	....	....	....	....	....	....
	III	....	....	....	....	....	....	....	....
25	I	$1.18	$10.00	3.68	31.00	4.51	38.00	4.93	41.50
	II	....	....	2.32	12.50	3.15	17.00	3.57	19.50
	III	....	....	....	....	....	....	....	....
30	I	2.73	38.00	5.23	72.50	6.06	84.00	6.48	90.00
	II	1.18	11.50	3.68	35.50	4.51	43.50	4.93	47.50
	III	....	....	2.32	12.50	3.15	16.50	3.57	19.00
35	I	3.73	84.00	6.23	140.00	7.06	159.00	7.48	168.00
	II	2.73	43.50	5.23	83.00	6.06	96.50	6.48	103.00
	III	1.18	11.00	3.68	34.00	4.51	42.00	4.93	46.00
40	I	4.18	137.00	6.68	219.00	7.51	246.50	7.93	260.00
	II	3.73	87.50	6.23	146.50	7.06	166.00	7.48	175.50
	III	2.73	38.50	5.23	74.00	6.06	86.00	6.48	92.00
45	I	4.36	182.50	6.86	287.00	7.69	321.50	8.11	339.00
	II	4.18	128.00	6.68	204.50	7.51	230.00	7.93	242.50
	III	3.73	71.50	6.23	119.50	7.06	135.50	7.48	143.50
50	I	4.55	223.00	7.05	346.00	7.88	386.50	8.30	407.50
	II	4.36	159.50	6.86	251.00	7.69	281.50	8.11	297.00
	III	4.18	101.00	6.68	161.00	7.51	181.00	7.93	191.00
55	I	4.64	255.00	7.14	392.50	7.97	438.00	8.39	461.00
	II	4.55	191.00	7.05	296.00	7.88	331.00	8.30	348.50
	III	4.36	126.50	6.86	199.00	7.69	223.00	8.11	235.50
60	I	4.73	284.50	7.23	435.00	8.06	485.00	8.48	510.50
	II	4.64	217.50	7.14	334.50	7.97	373.50	8.39	393.50
	III	4.55	152.50	7.05	236.50	7.88	264.50	8.30	278.50
65	I	4.82	313.50	7.32	476.50	8.15	530.50	8.57	558.00
	II	4.73	244.00	7.23	373.00	8.06	416.00	8.48	437.50
	III	4.64	176.50	7.14	272.00	7.97	303.50	8.39	319.50
70	I	4.91	347.00	7.41	521.50	8.24	579.50	8.66	609.00
	II	4.82	270.50	7.32	410.50	8.15	457.00	8.57	480.50
	III	4.73	200.00	7.23	305.50	8.06	341.00	8.48	358.50

[1] Based on yields, values, and costs given in preceding tables. The values per acre are rounded off to the nearest 50.

COST OF RAISING STANDS.

The costs in connection with raising white pine may be classed as initial and annual expenses. The former include the costs of formation (planting, sowing, and natural reproduction) at compound interest to the end of the rotation, together with interest on the initial value of the land. The latter include taxes on land and timber, and annual costs of protection and administration, both chargeable as annuities at a specific interest rate. Since the land remains an asset when the timber is cut, only the interest on it need be figured as an actual outlay.

VALUE OF THE LAND.

One of the chief arguments in favor of timber raising is that it presents a means of profitably utilizing waste lands. Wherever a greater income can be secured by some other use of the soil, timber growing can not be considered financially warranted. The ordinary situations in which it can be carried on with financial success include areas which are nonagricultural because of broken topography and high altitude, or a poor, stony, or sandy soil. A distance from market of 10 or 15 miles, with good level or down-grade roads, is not prohibitive, provided the soil is good enough to produce quality I yields. The ideal situation is one close to a good market where the soil is deep, fertile, and well-drained, but too steep and broken to have a high value. Land suitable for raising white pine can ordinarily be obtained in New England for from $3 to $7 per acre. In computing the costs of raising white pine given in this bulletin a land value of $5 per acre is assumed as average. The interest on the initial value of $5 per acre, computed for different periods, is shown in Table 12.

Initial Cost of Formation

Often, as on abandoned pastures adjoining farm woodlots, the young stand becomes established without entailing any cost. More often, however, rapid growing hardwood sprouts or seedlings handicap the pine, and their removal involves some expense. Sometimes, too, it is necessary to sow or plant the whole or part of the area. The costs of these operations are discussed elsewhere in this bulletin. In considering their influence upon the whole investment it is sufficient to deal simply with the total expense of formation without regard to the way in which it was incurred. Table 12 shows by decades the amounts to which formation costs of $3, $6, $9, $12, and $15 accumulate when at 4 and 6 per cent interest. In Tables 14 to 17 results where no cost of formation is incurred are also given.

Table 12.—*Costs of raising white-pine stands (not including taxes) at compound interest, by decades.*

Interest rate.	Age.	Cost of formation, carried to end of rotation.					Interest on land value of $5 per acre.	Protection and administration at 5 cents per acre.
		$3.	$6.	$9.	$12.	$15.		
	Years.							
4 per cent.	20	$6.57	$13.14	$19.72	$26.29	$32.87	$5.96	$1.49
	30	9.73	19.46	29.19	38.92	48.65	11.22	2.81
	40	14.40	28.81	43.21	57.61	72.02	19.00	4.75
	50	21.32	42.64	63.96	85.28	106.60	30.53	7.64
	60	31.56	63.12	94.68	126.24	157.79	47.60	11.90
	70	46.79	93.43	140.14	186.86	233.57	72.86	18.21
6 per cent.	20	9.62	19.24	28.86	38.48	48.11	11.04	1.84
	30	17.23	34.46	51.69	68.92	86.15	23.72	3.95
	40	30.86	61.72	92.57	123.43	154.29	46.43	7.74
	50	55.26	110.52	165.78	221.04	276.30	87.10	14.52
	60	98.97	197.93	296.90	395.86	494.82	159.94	26.66
	70	177.23	354.46	531.70	708.92	886.16	290.39	48.40

Protection and Administration.

Protection and administration may involve a slight annual outlay, though in States which employ an efficient patrol during the fire season that for the former may be so small as to be scarcely a factor in timber raising. Administration provides for time spent in looking over the property. In Table 12 an annual administrative and protective cost of 5 cents per acre is compounded at 4 and 6 per cent interest for 10-year periods up to the age of 70 years.

Taxes.

Tax assessments on timberlands are commonly based on rough appraisals in which the land and the timber are not considered separately.[1] The tax rate varies considerably, but a common one in the pine regions of New England is $2 per $100 on a two-thirds valuation. In computing the accumulated tax per acre for this bulletin land and timber were assumed to be valued separately. Since the value of the land is a constant one of $5 per acre, the taxes are figured as an annuity. The increase in value of the growing timber is taxed on the basis of the stumpage values given in Table 11, which implies that the taxable value of the stumpage remains reasonably constant for a 5-year period. The taxes accumulated for each period are carried at compound interest to the end of the rotation, when the total accumulations from all the periods represent the total accrued stumpage tax at a specified age. These amounts are shown in Table 13. The tax rate used is 1½ per cent on full valuation, corresponding to 2¼ per cent on a two-thirds valuation. This rate is slightly higher than the usual one, and together with the strict valuation imposed by Table 11 results in accumulated taxes probably in excess of the actual amounts. This was done to avoid the danger of underrating the total cost of growing the timber. With a lower tax rate the age at which the stand can be most profitably cut would be slightly extended and the profits increased.

The relation between stumpage value, taxes, and other producing costs, and their effect on the length of the rotation, is shown in Table 34, Appendix.

---

[1] Taxation of forest lands is discussed in a paper under this title by J. H. Foster (Biennial Report, 1907-8, Forestry Commission, State of New Hampshire, pp. 47-118), and also in a report of the Wisconsin State Board of Forestry in cooperation with the Forest Service, entitled "Taxation of Forest Lands in Wisconsin," by A. K. Chittenden and Harry Irion.

TABLE 13.—*Accumulated taxes on land and timber at rate of 1½ per cent on full valuation, at compound interest, by decades to the seventieth year.*

[Distance from stand to market permits a daily haul, per team, of 1,000 and 3,000 board feet of lumber.]

Interest rate.	Age.	Taxes on land.	Taxes on timber.[1] Quality I. Daily haul per team. 1,000 board feet.	Taxes on timber.[1] Quality I. Daily haul per team. 3,000 board feet.	Taxes on timber.[1] Quality II. Daily haul per team. 1,000 board feet.	Taxes on timber.[1] Quality II. Daily haul per team. 3,000 board feet.	Taxes on timber.[1] Quality III. Daily haul per team. 1,000 board feet.	Taxes on timber.[1] Quality III. Daily haul per team. 3,000 board feet.
	Years.							
4 per cent	30	$4.21	$0.81	$4.48	....	$1.41	....	....
	40	7.13	11.79	27.82	$4.64	14.22	$0.92	$4.95
	50	11.45	45.89	91.68	25.91	56.14	10.98	27.00
	60	17.85	107.86	209.53	69.65	137.82	36.50	76.03
	70	27.32	213.26	401.23	144.42	274.69	83.46	163.35
6 per cent	30	5.93	.85	4.79	....	1.47	....	....
	40	11.61	12.92	31.50	4.94	15.70	.96	5.44
	50	21.78	54.12	111.48	29.56	66.35	12.13	30.91
	60	40.00	140.46	280.48	87.18	178.63	43.82	94.74
	70	72.60	310.29	602.07	201.35	397.43	110.68	225.27

[1] Assessments assumed to be made at 5-year intervals, on the basis of the stumpage values given in Table 11, and the taxes for each 5-year period (accumulated as an annuity) carried at compound interest to the end of the rotation. The figures given in the table are thus the sum of the accumulated taxes for the last 5-year period plus those for all preceding 5-year periods at compound interest to the specified year.

RETURNS TO BE EXPECTED.

The value of an investment in raising white pine may be determined by finding either (1) the precise rate of interest at which the stumpage value exactly equals the cost of growing, or (2) the amount of surplus profit when the stumpage value exceeds the cost of growing, computed at any desired rate of interest. The first of these methods is illustrated in Table 14, and the second in Tables 15, 16, and 17, which show the highest surplus profit or the least loss resulting when the costs are computed at 4, 5, and 6 per cent compound interest. From Table 14 it is apparent that the rate of interest is highest in quality I stands, close to market, which were started by natural seeding; and that it is lowest in planted stands in quality III situations, at some distance from market. This table also shows that investments which return a high rate of interest mature earlier than those yielding a lower rate.

These figures can be used safely in estimating the returns from investments in which the costs are no higher and the anticipated yields no lower than those given in preceding tables. It should be remembered, however, that they are based on the yields of fully stocked stands, and in using them it is well to allow for understocked and unmerchantable portions of the stand by assuming the area to be smaller but fully stocked. A deduction of from 10 to 20 per cent of the area, depending upon intensity of management, should be ample.

TABLE 14.—*Rate of interest on the total investment earned by second-growth stands under different conditions.*[1]

Amount hauled daily per team.	Cost of formation.	Quality I.		Quality II.		Quality III.	
		Most profitable rotation.	Interest rate.	Most profitable rotation.	Interest rate.	Most profitable rotation.	Interest rate.
Board ft.		*Years.*	*Per cent.*	*Years.*	*Per cent.*	*Years.*	*Per cent.*
1,000	....	40	7.7	40	6.6	50	5.3
	$3.00	40	6.7	45	5.7	50	4.5
	6.00	40	5.9	45	5.0	50	3.9
	9.00	40	5.3	45	4.5	50	3.5
	12.00	40	4.9	45	4.1	55	3.0
	15.00	40	4.5	45	3.8	55	2.7
2,000	....	35	9.1	40	7.8	45	6.4
	3.00	35	7.8	40	6.8	45	5.5
	6.00	40	7.1	40	6.1	45	4.9
	9.00	40	6.5	40	5.6	50	4.4
	12.00	40	6.0	45	5.1	50	4.0
	15.00	40	5.6	45	4.8	50	3.7
3,000	....	35	9.6	40	8.2	45	6.7
	3.00	35	8.2	40	7.2	45	5.8
	6.00	40	7.4	40	6.4	45	5.2
	9.00	40	6.8	40	5.8	45	4.7
	12.00	40	6.3	45	5.4	45	4.3
	15.00	40	5.9	45	5.0	50	4.0
4,000	....	35	10.0	40	8.3	45	6.8
	3.00	35	8.3	40	7.3	45	5.9
	6.00	40	7.5	40	6.6	45	5.3
	9.00	40	6.9	40	6.0	45	4.9
	12.00	40	6.5	40	5.5	45	4.4
	15.00	40	6.1	45	5.1	50	4.1

[1] Based on the stumpage and cost data given in preceding tables. The interest rates were determined graphically by curving the profits and losses found by computing the initial and annual expenses at several fixed rates of interest. This method, devised by Mr. W. B. Barrows, is described in the Proceedings of the Society of American Foresters, vol. 8, No. 3, p. 362.

TABLE 15.—*Profit and loss per acre from raising white pine under different conditions, showing ages between which stand could be cut with profit, the most profitable age, and the maximum profit,* **as a 4 per cent investment.**

Daily hauling capacity for one team.	Cost of formation.	Quality I.			Quality II.			Quality III.		
		Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.
Bd.ft.		*Years.*	*Years.*		*Years.*	*Years.*		*Years.*	*Years.*	
1,000	....	30-*	50	$127.67	35-*	55	$84.25	40-65	55	$42.86
	$3.00	30-65	50	106.35	35-65	50	62.86	45-60	50	18.86
	6.00	35-60	50	85.03	40-60	50	41.54	....	50	− 2.46
	9.00	35-60	45	64.97	40-55	45	23.31	....	45	−24.61
	12.00	35-55	45	47.44	45	45	5.78	....	45	−42.14
	15.00	40-50	45	29.92	....	45	−11.74	....	45	−59.66
2,000	....	20-*	50	216.11	30-*	50	153.01	35-*	55	95.98
	3.00	25-*	50	194.79	30-*	50	131.69	40-65	55	70.04
	6.00	25-65	50	173.47	35-65	50	110.37	40-60	50	45.91
	9.00	30-65	50	152.15	35-60	50	89.05	45-55	50	24.59
	12.00	30-60	50	130.83	35-60	50	67.73	50	50	3.27
	15.00	30-60	45	113.17	40-55	50	46.41	....	45	−18.22
3,000	....	20-*	50	245.38	25-*	55	177.45	35-*	55	113.41
	3.00	25-*	50	224.06	30-*	50	154.51	35-*	55	87.47
	6.00	25-65	50	202.74	30-65	50	133.19	40-65	55	61.77
	9.00	30-65	50	181.42	35-65	50	111.87	40-60	50	40.45
	12.00	30-60	50	160.10	35-60	50	90.55	45-55	50	19.13
	15.00	30-60	45	140.74	35-60	45	72.11	....	50	− 2.19
4,000	....	20-*	50	260.22	25-*	55	189.25	30-*	55	122.31
	3.00	25-*	50	238.90	30-*	50	166.10	35-*	55	96.37
	6.00	25-65	50	217.58	30-65	50	144.78	40-65	55	70.43
	9.00	25-65	50	196.26	35-65	50	123.46	40-60	50	48.55
	12.00	30-60	50	174.94	35-60	50	102.14	45-55	50	27.23
	15.00	30-60	45	154.74	35-60	45	82.70	45-50	50	5.91

NOTE.—The stars indicate an age of over 70 years. The computation was not extended to stands over 70 years old, although under certain conditions a rotation of more than 70 years could undoubtedly be employed with profit

TABLE 16.—*Profit and loss per acre from raising white pine under different conditions, showing ages between which stand could be cut with profit, the most profitable age, and the maximum profit,* **as a 5 per cent investment.**

Daily hauling capacity for one team.	Cost of formation.	Quality I.			Quality II			Quality III.		
		Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.
Bd. ft.		*Years.*	*Years.*		*Years.*	*Years.*		*Years.*	*Years.*	
1,000	....	30–60	45	$96.88	35–60	45	$56.21	45–55	50	$10.75
	$3.00	35–55	45	69.92	40–50	45	29.25	....	45	− 18.20
	6.00	35–50	45	42.97	45	45	2.30	....	45	− 45.15
	9.00	40–45	45	16.01	....	40	− 25.86	....	40	− 70.87
	12.00	....	40	− 4.95	....	40	− 46.98	....	35	− 89.08
	15.00	....	40	− 26.07	....	40	− 68.10	....	35	−105.62
2,000	....	25–60	50	179.32	30–65	50	120.08	40–60	50	58.14
	3.00	25–60	45	151.13	35–60	45	91.17	40–55	50	23.74
	6.00	30–55	45	124.18	35–55	45	64.22	....	45	− 4.11
	9.00	30–55	45	97.22	40–50	45	37.26	....	45	− 31.07
	12.00	35–50	45	70.27	40–45	45	10.31	....	45	− 58.02
	15.00	35–50	45	43.31	....	45	− 16.65	....	40	− 80.77
3,000	....	20–65	50	207.26	30–65	50	142.15	35–65	50	73.66
	3.00	25–60	45	178.03	30–60	45	111.68	40–55	50	39.26
	6.00	30–55	45	151.08	35–55	45	84.73	45–50	45	9.37
	9.00	30–55	45	124.12	35–50	45	57.77	....	45	− 17.59
	12.00	30–50	45	97.17	40–50	45	30.82	....	45	− 44.54
	15.00	35–50	45	70.21	40–45	45	3.86	....	40	− 70.12
4,000	....	20–65	50	221.36	25–65	50	153.36	35–65	50	81.59
	3.00	25–60	45	191.65	30–60	45	122.10	40–55	50	47.19
	6.00	25–60	45	164.70	35–55	45	95.15	45–50	45	16.24
	9.00	30–55	45	137.74	35–55	45	68.19	....	45	− 10.72
	12.00	30–55	45	110.79	40–50	45	41.24	....	45	− 37.67
	15.00	35–50	45	83.83	40–45	45	14.28	....	40	− 64.71

TABLE 17.—*Profit and loss per acre from raising white pine under different conditions, showing ages between which stand could be cut with profit, the most profitable age, and the maximum profit,* **as a 6 per cent investment.**

Daily hauling capacity for one team.	Cost of formation.	Quality I.			Quality II.			Quality III.		
		Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.	Profitable ages for cutting.	Most profitable rotation.	Profit or loss.
Bd. ft.		*Years.*	*Years.*		*Years.*	*Years.*		*Years.*	*Years.*	
1,000	....	30–50	45	$63.08	40–50	45	$23.53	....	45	−$23.41
	3.00	35–45	40	27.60	....	40	− 13.99	....	35	− 59.43
	6.00	....	40	− 3.26	....	40	− 44.85	....	35	− 82.49
	9.00	....	40	− 34.11	....	30	− 73.93	....	35	−105.55
	12.00	....	35	− 60.09	....	30	− 91.17	....	35	−128.61
	15.00	....	25	− 77.82	....	30	−108.40	....	35	−151.66
2,000	....	25–55	45	142.12	30–55	45	84.28	40–50	45	17.20
	3.00	30–50	45	100.83	35–50	45	42.99	....	45	− 24.09
	6.00	30–50	40	64.90	40–45	40	5.86	....	30	− 55.77
	9.00	35–45	40	34.05	....	40	− 24.99	....	30	− 72.99
	12.00	40	40	3.19	....	40	− 55.85	....	30	− 90.23
	15.00	....	40	− 27.67	....	35	− 83.97	....	30	−107.46
3,000	....	25–55	45	168.17	30–55	45	104.35	40–50	45	30.53
	3.00	25–55	45	126.88	35–50	45	63.11	....	45	− 10.76
	6.00	30–50	40	87.38	40–45	45	21.81	....	40	− 46.92
	9.00	35–45	40	56.53	....	40	− 8.21	....	30	− 68.59
	12.00	35–45	40	25.67	....	40	− 39.07	....	30	− 85.83
	15.00	....	40	− 5.19	....	40	− 69.93	....	30	−103.06
4,000	....	20–55	45	181.37	30–55	45	114.62	40–55	45	37.31
	3.00	25–55	45	140.08	35–50	45	73.33	....	45	− 3.98
	6.00	30–50	45	98.78	35–50	45	32.03	....	40	− 41.52
	9.00	35–50	40	67.91	40	40	.33	....	30	− 66.37
	12.00	35–45	40	37.05	....	40	− 30.53	....	30	− 83.61
	15.00	40	40	6.19	....	40	− 61.39	....	30	−100.84

MANAGEMENT.

In the preceding chapter it was shown that white pine raising can usually be counted on to bring returns of 4, and often of 6, per cent or more. It thus offers a means of deriving a substantial net income from land which would otherwise be almost or wholly useless. Trees demand but little time and labor as compared with other crops, for while some care must be given to make sure that the young stand gets the proper start, its later development may be left largely to nature, with but little expense besides taxation and protection—common charges on any property.

While nature can be relied upon to produce the lumber yields and incomes given in Tables 6, 14, 15, 16, and 17, the yield, and consequently the value of white-pine stands, can be materially increased by artificial means, such as thinnings, improvement cuttings, and efficient methods of reproduction, all commonly combined under the term "management." Of course, no detailed plan of management can be given which will apply alike to all white-pine stands. Knowing the characteristics of the tree as outlined in the first part of this bulletin, however, it is possible to formulate broad methods of management for pure and mixed stands of white pine. Local conditions, especially in mixed stands, will necessarily call for modifications in the general plan, but these will not be wide departures, and in all likelihood will suggest themselves as the management of the stand proceeds.

SECOND GROWTH.

Stands are said to be even aged if the trees composing them vary in age by less than 20 years. They are called pure if they contain 80 per cent or more of a single species, and mixed if they contain two or more species no one of which forms 80 per cent of the stand. Pure, even-aged stands of second growth seldom develop on land not previously cultivated or burned over, even where the original stand consisted chiefly of pine. This has led to the erroneous belief that pine would never follow pine. The failure of pine to succeed itself is due to the slow growth and intolerance of shade of the young seedlings, which are overtopped by the various broadleaf trees which spring up on clearings. The resulting stand may be exclusively of hardwoods or contain a limited proportion of pine. Even on land previously cultivated, mixed stands will appear when the area receives seed from both pine and hardwoods.

Pure, Even-aged Stands.

Pure, even-aged stands of white pine yield more lumber per acre, age for age, than pure stands of any other species in the Northeast. This is due partly to their rapid growth and partly to the low grades of lumber which can be marketed. Pine branches are so persistent that lumber of higher grades than box boards, match stock, and a very little sash and blind stock can hardly be produced in short rotations except by means of systematic pruning (see p. 38).

ROTATION.

Under "White pine as an investment" it was shown that the age at which the pine should be cut in order to secure the greatest profit varied with the rate of interest used. The lower the interest, the greater will be the age, called the age of financial maturity. If, for example, the investor demands only 4 per cent, the stand can, under most conditions, be profitably left until it is 50 years old. If 6 per cent is desired, however, rotation should not be over 40 or 45 years. Unfortunately the financial maturity of a stand at the interest rates given rarely coincides with its volume maturity in board feet. From the standpoint of volume the pine has matured at the age when its average annual growth per acre is greatest. The age at which volume matures is shown for different qualities in Table 7. In quality I situations the volume maturity in board feet occurs, as a rule, when the stand is from 55 to 65 years old; in quality II, between 70 and 80 years; and in quality III, between 85 and 95 years. In the future, when timber is much scarcer than it is now, the volume maturity may often coincide with or precede the financial maturity. At the present, however, it is the latter which should be the guide in management.

Since the stand should be removed only during heavy seed years, which occur at intervals of from 3 to 7 years, it can rarely be cut in precisely the year when it is financially mature. A good rule to follow if the stand is to be cut clear is to remove it during the seed year next following maturity. If two or more cuttings are planned, the first may be made during a year of prolific seed production preceding maturity by from 3 to 7 years, and the later cuttings in subsequent seed years.

THINNINGS.

In dense stands of pine there is an intense competition between individuals for light and growing space. As a dominant tree falls behind its more vigorous neighbors it becomes in turn codominant, intermediate, and overtopped, and finally dies for lack of light. The struggle is thus most critical in the dominant class. The other classes are on the road to elimination, though until finally suppressed they continue to crowd the dominant trees and retard their volume growth.

Thinnings aim to increase the volume growth of dominant trees by removing from time to time trees of other classes which are unduly crowding them (see Pl. V). In this way the total growth of the stand is concentrated in the smallest number of thrifty trees

FIG. 1.—A 50-YEAR-OLD WHITE PINE STAND BEFORE THINNING. SOUTHERN NEW HAMPSHIRE.

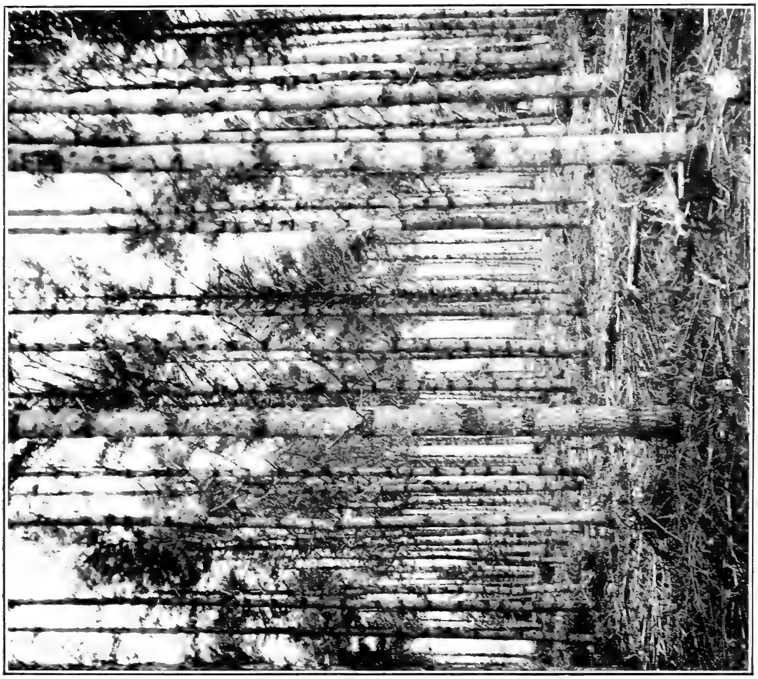


FIG. 2.—SAME STAND PROPERLY THINNED.

WHITE PINE PLANTATION, 22 YEARS OLD THINNED AT AGE OF 15 YEARS.

which will occupy the area. If these are pruned of branches to a height of 16 or 17 feet, the value of the future increment will be materially increased. At the same time the trees removed, which would otherwise be wasted, may yield a moderate return. As a result of successive thinnings at intervals of from 5 to 10 years, the aggregate yield, including the material saved in the thinnings, will be increased, while the trees finally harvested will be larger, sounder, and better formed than in unmanaged stands.

The best time to thin a stand is during the period of its most rapid height growth, though this occurs so early in its life that enough merchantable material to pay for the thinning can rarely be obtained. An early unremunerative thinning may, however, more than pay for itself by increasing the value both of the final stand and of the material removed in later thinnings (see Pl. VI).

In all thinnings any undesirable hardwoods which may be present should be removed. Thinnings should leave the stand uniformly opened up to an extent which insures that crowns of the trees left will not come together again for four or five years. More space should be left between the crowns when the trees are young and growth rapid than later. An average distance between the crowns of from 3 to 5 feet is probably sufficient in most cases, though the removal of undesirable hardwoods or of unsound or poorly formed pines may make somewhat larger openings unavoidable. Large openings in the crown cover, however, will result in poorly formed limby trees and should be avoided.

In quality I stands which have always been dense, a thinning may often be made with advantage as early as the fifteenth year. In stands which have been understocked in youth thinnings are, of course, unnecessary until considerably later, if warranted at all. Early thinnings, of course, represent a direct outlay, since little of the material removed will be fit even for cordwood. In farm woodlots such thinnings can often be made during leisure time without a real loss. The trees removed will be mainly codominant and intermediate. Dead and badly suppressed trees need not be cut, since they no longer interfere with the growth of the stand. Subsequent thinnings may be made at about the twentieth, twenty-fifth, and thirty-fifth year. Except that the last should be slightly heavier to allow the trees full space for volume growth up to the time of final cutting, the subsequent thinnings may be made in the same manner as the first. When the stand is 20 years old the material removed in thinning may be large enough for cordwood, and the operation pay for itself. Later thinnings should yield a profit. When necessary, the intervals between thinnings may be lengthened and the thinnings themselves made more severe. It is better, however, to thin lightly and often than heavily and at longer intervals.

In quality II situations, where the growth is slower, thinnings should be made lightly and often, in order not to expose the soil too much. Because of the relatively low returns to be expected from quality III stands, unremunerative thinnings in them may not be advisable. When enough fuel wood can be cut to make thinnings pay, however, one or two may be made with advantage.

The amount of wood removed in thinnings, irrespective of the age of the stand, is usually from 15 to 40 per cent (average about 26 per cent) of the total volume. It is less in previously thinned than in unthinned stands. The number of trees removed varies widely with the age of the stand and its past density. Ordinarily it ranges between 20 and 60 per cent, with an average of about 45 per cent.

PRUNING.[1]

Pruning has usually been condemned as expensive and likely to produce pitch pockets and loose knots, and at present is not widely practiced. While certain defects often result from pruning, these are in most cases due to wrong methods, and should not be considered evidence against pruning in general. There is reason to believe that if properly done the money expended in pruning will yield substantial returns.

Pruning should remove all dead branches, and usually a whorl or two of the lower live branches, flush with the trunk. Care should be taken not to injure the trunk; the saw is perhaps the safest and best instrument. By mounting it on a light 12-foot pole, the branches can be pruned to a height of 17 feet, thus providing for a clear lumber increment over one 16-foot log. The cost will be from 5 to 10 cents per tree. Pruning can be done at any season, but for live branches late fall or early winter is probably best, since the tree will suffer less from bleeding than at other seasons.

To be worth while, pruning must be done early in the life of the stand, preferably at an age of from 20 to 30 years, while the branches are still small and there is but a small amount of low-grade lumber at the heart. A safe rule is to prune to a height not over half that of the tree. A clear length of 17 feet would thus indicate a total height for the tree of 34 feet, but it is better to begin pruning when the tree is smaller, increasing the clear length by a subsequent pruning. In this way the maximum time is given for the accumulation of clear lumber during the remaining 30 years or more of the financial rotation.

Only those trees which are to be left until the final cutting should be pruned. For stands which are to be consistently thinned, the

[1] This subject is discussed in detail in "Silviculture of White Pine," by F. B. Knapp (Bulletin 106, Mass. Forestry Association, 4 Joy St., Boston). An example of the application of pruning to second-growth white pine is the stand belonging to and managed by Mr. O. M. Pratt, Holderness, N. H.

number of trees per acre at the end of a 50 or 60 year rotation, and therefore the number to be pruned, will probably be less than 200. Thrifty trees, scattered evenly through the stand, should be selected for pruning, and these should be favored in subsequent thinnings. In fact, pruning is practically useless if unaccompanied by thinning. Plantations in which pruning is to be practiced may be spaced wider than otherwise, and the saving in plant material and labor may often exceed the cost of pruning, which, in addition, will bear interest for a less number of years.

FINAL CUTTING AND NATURAL REPRODUCTION.

The mature crop should be harvested in such a way that the ground will be left evenly stocked with thrifty reproduction. Since pine seedlings soon demand full light, the removal of the mature stand should be complete, though not necessarily in a single year. There are four ways of providing the necessary seed supply for the cut-over area: (1) Clear cutting the entire stand during the fall and winter of a prolific seed year; (2) clear cutting in strips from 100 to 150 feet wide to be seeded from the side; (3) clear cutting with scattered seed trees; (4) the shelter-wood method of successive partial cuttings over the whole area.

Clear cutting the whole stand.—Clear cutting the whole stand in one operation is the cheapest method, since it is not necessary to return later for a second cut. It is especially suitable for small areas of 4 or 5 acres with adjacent bodies of seed-bearing pine. If done after a heavy fall of seed, young pines will usually appear in abundance the subsequent spring. Care must be taken for the first 5 or 6 years to see that valueless rapid-growing hardwood seedlings and sprouts, which are usually present, do not choke out the pine (see Pl. III, fig. 2). When young pine seedlings are thus threatened, the slender hardwood saplings should be lopped back at a height of from 1 to 2 feet from the ground with a sharp corn knife or brush hook. This is known as a "disengagement cutting." It should be done when the young stand is 6 or 8 years old, when the pines will usually be from 2 to 6 feet and the hardwoods from 6 to 12 feet high. If released at this age the young pines should have little trouble in keeping down the hardwoods thus handicapped.

The cost of lopping will vary with the size of the saplings and the efficiency and cost of labor. In a fairly dense stand a good man can cover from 1 to 2 acres per day, provided the hardwoods are small enough to be severed with a single stroke of the knife. Lopping should be done during the summer, if possible, since the hardwoods are apt to sprout less vigorously then than after a cutting in winter or early spring. Often a second cutting four or five years later will be necessary. This will consist chiefly in cutting back the more aggressive sprouts which have succeeded in overtaking the young pines. Really valuable hardwoods, such as white ash or black cherry, need not, of course, be cut back with the others.

A judicious burning of the cleared area would destroy much of the competing vegetation, expose the mineral soil, and destroy the slash left after logging. On the other hand, it would also destroy most of the pine seed. It is not safe, therefore, to use fire except when adjacent timber insures an abundant seed supply or when artificial reproduction is contemplated. Furthermore, it involves some additional expense and inevitably results in more or less serious damage to the soil. Lopping of branches from the treetops after logging will cause the slash to lie flat on the ground, and so present the least risk of being ignited. At the same time it will give the young seedlings the shade they need, and by its decay add to the moisture retaining humus layer essential for the best growth of the stand. In situations exposed to intense sunlight or to drying winds the protection given by the lopped branches is especially beneficial. On clear-cut pine lots in New England excellent reproduction springs up in old slash, while open places often bear little or no young growth. Along railroad rights of way and in other places where the fire risk is great, the brush should, of course, be piled or scattered and burned. In such cases, however, it may be necessary to reproduce the stand by artificial means.

Clear cutting in strips.—Under this system the stand is cut in strips from 100 to 150 feet wide, while strips of equal width are left to seed up those cut over. When this is accomplished, the remainder of the timber is removed. Manifestly, enough timber must be left to warrant the expense of a second logging, and the total area or total yield of the stand must, therefore, be twice as large as when one cutting is made. With average yields a minimum area of 10 or 12 acres might warrant logging by this method, provided about half of the timber is removed in each of the two cuttings. On level land the strips should lie parallel and in a direction which will insure that the prevailing winds will blow the seed across the cleared areas. In rough country this arrangement will often have to be modified in order to facilitate logging. If it becomes necessary to cut the strips parallel to the prevailing wind, they should be narrower than otherwise, to insure a complete seeding. In making the second cut, if there are no adjacent seed-bearing trees to windward, reproduction must be secured by the seed tree or the shelterwood method, or artificially.

Where the area comprises 20 acres or more, with fairly uniform conditions, the strip method may be extended to allow 3, 4, or 5 cuttings at fairly regular intervals during the rotation. Thus, if the contemplated rotation was 60 years, one-third of the stand could be removed every 20 years, or one-fourth every 15 years, or one-fifth every 12 years. The strips should run as nearly as possible at right angles to the prevailing winds. While, as with two cuttings, a width for the strips of 100 to 150 feet is best, the width of the intervening strips of standing timber must be sufficient to insure that the 3, 4, or 5 cuts will entirely remove the stand. If, for example, the average acre yield at 60 years of a 16-acre tract of pure white pine is 30,000 board feet, and the installation of a portable mill is warranted by a cut of 100,000 board feet, or $3\frac{1}{3}$ acres, 5 such cuttings at 12-year intervals would be possible with a rotation of 60 years. The side of the stand most nearly parallel to the prevailing wind should be divided into 5 parts, and each of these into approximately equal subdivisions from 50 to 100 feet wide. Each of the cuttings will then follow every fifth strip at right angles to the prevailing wind. Very few stands, however, are uniform throughout, and the width of the strips will have to depend somewhat upon local variation in the yield.

Any system of sustained yield through regular cuttings presupposes the existence of a reasonably steady market for the grades of lumber supplied. White pine lumber of medium and low grades promises to remain as steadily in demand as that of any other species in the Northeast. Even white pine lumber, however, will fluctuate in value, and the temptation will often be strong to overcut when the market is high, and lightly or not at all when the demand is poor. While modification in the original plan can be made only at a sacrifice in regularity in ensuing yields, it can not always be avoided, and constitutes a defect in the strip system. Absolute regularity, however, is often undesirable, even from a silvicultural standpoint, since a year's delay or hastening of the cut to take advantage of a seed year may greatly facilitate reproduction.

One great advantage of the strip method over clear-cutting the whole stand is the greater certainty of reproduction it offers. Should the young reproduction be destroyed by fire, the standing timber to windward can be depended upon to reseed the area. In fact, a light fire just before a heavy fall of seed, provided it is not allowed to spread into adjacent timber, may prove of great value by exposing the mineral soil and killing existing vegetation. As when only two cuttings are made, the last strips to windward may be reproduced by leaving seed trees or by planting or sowing. Disengagement cuttings will often be necessary to remove competition from fast-growing hardwood sprouts and underbrush.

Clear cutting with scattered seed trees.—In this method natural reproduction is secured by leaving three or four mature seed-bearing trees to the acre (see Pl. IV, fig. 2). These should be distributed as evenly as possible, but located with reference to the prevailing winds in a way to insure the most effective distribution of seed. Seed trees should be windfirm. Those with large crowns and relatively thick trunks are least likely to be thrown. If, however, there is any question of windfirmness, it is usually best to leave the seed trees in groups of three or four for mutual protection.

When a thrifty reproduction has been secured, seed trees should be removed if it is profitable to do so. If they are well formed and sound, however, they may be left until the land is again cut over. In this way the cost of their removal will be lessened and lumber of larger size and possibly of better quality secured.

If seed trees are to be left, the stand may be logged before seed fall in a year of heavy production. This permits the logged area to be burned over lightly, should it be thought necessary to get rid of bushes and hardwood sprouts and seedlings. As in the other methods, disengagement cuttings should be made if the pine seedlings are threatened by hardwoods.

The seed-tree method has the advantage over the other methods described in that the area which can be cut over at any one time is unlimited. Since only one cutting is made in a rotation, there is no periodic income as in the strip method; but, on the other hand, the expense and trouble of logging come only once.

Shelterwood method.—The shelterwood or "stand" method removes the trees by successive thinnings or partial clearings at intervals of a few years. The object is to gradually establish thrifty reproduction under the best possible conditions and to preserve a seed supply in case of disaster to the young stand. In Germany, where the system originated, and where economic conditions allow of its intensive application, a large number of successive thinnings are made, classed as "preparatory," "seed," and "final" cuttings. The preparatory cuttings aim to increase the air circulation in dense stands, and thus facilitate decay of the humus and exposure of the mineral soil. They also stimulate seed production by admitting light to the tree crowns. From 25 to 40 per cent of the least desirable trees are removed, which reduces the density of the crown cover about one-fourth and leaves the dominant trees with their crowns separated by a space of from 3 to 5 feet. A few years later, when the soil is in good condition and seed production assured, the seed cutting is made. This is done during a seed year, and reduces the crown cover to at least one-half its original density, in order that sufficient light may be admitted for the expected reproduction. When the latter is so large, thrifty, and uniformly distributed as to leave no doubt of its success, the shelter trees are removed. If the seedlings show need of increased light before the final cutting, as they may within 3 or 4 years after the seed cutting, some of the remaining trees must be removed in advance. The whole thinning process takes from 15 to 20 years. At its conclusion, should it prove successful, a thrifty stand of young trees, all of which are making rapid height growth, occupies the ground. The chief disadvantages of this method are the expense involved in logging, the damage to young growth caused by the removal of the larger trees, and the fact that, with the amount of light necessary for the pine seedlings, many tolerant hardwoods are likely to spring up and suppress the former. For white pine, therefore, this method should be modified so that only two cuttings, the seed and the final, are made. The first is made during an abundant seed year, and consists of a very heavy thinning which reduces the crown density fully one-half, entailing the removal of more than one-half the trees. Logging operations should disturb the leaf litter and expose the mineral soil for the germination of the pine seed. The trees left should be such of the dominant ones as give best assurance of windfirmness and seed-producing capacity. Good reproduction can be expected under these conditions. To insure the uniform stocking of the area, however, shelter trees are left standing until after at least the next seed year. All of them are then removed, when the mineral soil is again exposed and a chance given for new reproduction to take the place of that destroyed in logging. If logging is done in winter, however, when many of the seedlings are covered with snow, few of them will be damaged.

The slash left after each cutting should be lopped and scattered on the ground, or piled in the larger openings and burned. A disengagement cutting will probably be necessary a few years after the removal of the older trees.

This method has the advantage over that of leaving seed trees in that the entire stand is utilized, no trees being sacrificed to secure reproduction. It preserves a moist seed bed and insures the seedlings protection against too much light during their first year and against frost and drying winds up to the time when they are able to withstand them. By fostering a rank growth of weeds, underbrush, and hardwood seedlings, however, it offers an element of danger to the young pine (see Pl. V, fig. 1). Logging is more expensive than in clear cutting, with or without seed trees, because the ground is gone over twice and scattered trees must be taken in each operation.

Mixed Stands.

COMPOSITION AND IMPROVEMENT.

White pine grows in such a variety of mixtures, both with hardwoods and with other conifers, that it is impossible to outline definite rules for management that will fit all cases. In general, however, mixtures may be classed as desirable and undesirable. A desirable mixture is one in which the pine is well distributed among and overtops other valuable or more tolerant species. It was in such mixtures that the white pine of the original forests reached its best development. On suitable soils valuable hardwoods may be encouraged, provided the pines have received a sufficient start to keep their crowns above those of their associates. The diameter growth of pine in suitable mixtures, unlike that in pure stands managed on short rotations and unpruned, is accompanied by a marked improvement in the quality of the lumber, due to its greater freedom from knots. This comes about through the natural pruning of the pine branches by the relatively low and supple hardwood crowns. Another advantage of mixed stands consists in the relative freedom of the pine tops from damage by weevils, due to the isolated position of the pine among broadleaf trees inhabited by insect-eating birds.

Among the trees desirable for cultivation with white pine are beech, sugar, and red maple, yellow birch, basswood, red oak, white ash, and black cherry. These are arranged approximately according to ability to endure shade, beech being the most tolerant, cherry the least. Though their present economic value is relatively low, the tolerant species except red maple are also the slowest growing, which enhances their value as an understory for white pine. Cherry, ash, and red oak, on the other hand, produce lumber fully as valuable as that of white pine, but their rate of growth is only a little slower than that of the latter. Each class of associates, therefore, has a characteristic value in mixture with pine. As compared with pure stands managed on short rotations, the yield of the latter in a mixed stand may be considerably reduced, but where a higher quality of pine lumber is desirable and a market exists for the hardwoods, mixed stands operated on somewhat longer rotations are worthy of consideration.

Among the inferior associates of white pine are gray birch, large and small toothed aspen (popple), fire cherry, pitch pine, and jack pine. Most of these are undesirable simply because they monopolize ground upon which better species might be growing. Gray birch, however, is an active menace to any young pine in its vicinity, since its sprouts, swaying in the wind, soon kill the tender upper shoots of young pines growing near them.

TREATMENT.

The success of pine among hardwoods depends, for one thing, upon its overtopping the other species. This can usually be brought about by one or more disengagement cuttings made at about the time the pine is entering upon the period of its most rapid height growth. To secure mixed stands, of course, disengagement cuttings need not be as thorough as for pure pine stands, since the pines will be scattered, and only the hardwood saplings near them need be cut. It will be well, however, to remove inferior trees like gray birch, aspen, and fire cherry wherever they appear to threaten the existence of better species, such as white ash, red oak, and black cherry. Subsequent weedings made at intervals of a few years will gradually remove from the stand all undesirable species. Stands should be kept fairly dense, however, and no trees need be removed which appear to be succumbing to the competition of more desirable associates. The expense of improving the composition and increasing the value of mixed stands should be relatively small.

The growth of valuable broadleaf seedlings which, like white ash, sprout vigorously from the stump may be accelerated by cutting them back when the last of the original stand is finally removed. The "seedling sprouts" thus produced grow very rapidly, and soon attain a commanding position in the stand. Ash and black cherry cast only a light shade, and the presence with the pine of a reasonable number of those trees will greatly increase the value of the stand, both through their value for lumber and through their tendency to clear the pine trunks of branches.

OLD GROWTH.

Only scattered remnants of the original white-pine forests remain. These, however, are being logged in such a way that the complete disappearance of pine from such areas is threatened. Attempts to secure natural reproduction have rarely been successful, either because of defects in management, or fire.

While fire more than any other agency may play havoc with the forest, yet, if rightly used in connection with lumbering, it may be the means of insuring a natural growth of white pine on cut-over areas. The soil on which white pine does best is good enough to support many kinds of woody undergrowth, as well as relatively worthless broadleaf trees. As long as the shade from the old pines is dense the undergrowth is kept down. When the pine reaches an advanced age, however, the crown cover becomes thinner and the woody and herbaceous undergrowth increases in abundance. When the stand is finally cut nothing remains to hinder the development of the brush and hardwoods. Should a fire burn over the area just before a heavy seed year, however, and should the cutting follow immediately after seed fall, an abundant stand of pine reproduction is almost sure to come in, giving competing vegetation little room in which to grow. The problem from then on consists simply of protecting the young growth from fire.

Since it is almost impossible to prevent occasional fires from burning over large areas of pine slashings and destroying the young reproduction upon them, it is necessary to provide some means of reseeding such areas. This can be done either by leaving scattered seed trees or, better still, by removing the stand by the shelterwood method. In either case cuttings should be made only during years of heavy seed production. In most cases a careful burning over of the surface prior to the seed fall is necessary. The areas dealt with are ordinarily so large that disengagement cuttings are out of the question.

The seed-tree method has been employed in the white and Norway pine stands on the Minnesota National Forest (see Plate VII). Owing to the inadequacy of the law under which cuttings were made, however, it has not proved satisfactory except under accidental combinations of circumstances, such as the occurrence of severe ground fires before and not after a seed fall. The law provides that 10 per cent (originally 5 per cent), by volume, of the trees above 10 inches diameter breast high shall be left as seed trees. Since no adequate provision was made for the distribution of these, spaces left without seed trees were often too large, and very little reproduction resulted. The stand was cut not only during seed years, but also in years when there was absolutely no seed production. In the absence of cultural fires to free the ground from competing growth before the seed fall, the benefits of cutting during seed years are minimized, since most of the reproduction, even if abundant, is killed by the dense brush that rapidly springs up. On some areas which had been burned over during the spring or summer of a seed year and logged the following fall and winter, reproduction was excellent. On many of these, however, the young pine was killed by subsequent fires, and before the next seed year the ground was again covered with brush.

In lumbering old stands by the shelterwood method the first cutting should be made during a seed year and should be heavy enough to provide sufficient light for the pine seedlings without unduly encouraging the growth of brush. If reproduction is satisfactory—that is, if it should average at least 2,000 well-distributed seedlings per acre—a second cutting should be made during the first heavy seed year after the young pines are 5 or 6 years old. The stand may be cut clear at this time if the fire risk is small and the expense of leaving seed trees prohibitive. If, however, too much brush has sprung up since the first cutting, the ground should be thoroughly burned over in the spring or summer of the seed year in which the second cutting is made and seed trees or even enough of the stand to warrant a later cutting left on the ground.

Should the shelterwood method be thought too expensive, the seed-tree method may be used with good results if the cutting—made during a full seed year—is preceded by a thorough surface burning. The seed trees should be selected in advance from the most windfirm of the pines, and should be protected from surface fires by trenching or some other means. They should be well distributed at least 2 or 3 to the acre. Before each subsequent seed year, areas on which reproduction is poor should be carefully burned over.

WHITE PINE FOR WINDBREAKS AND RESERVOIR PROTECTION.

White pine is an excellent tree for windbreaks and shelter belts, and is planted largely for this purpose in the plains States. Its treatment as a shelter-belt tree is discussed in Forest Service Bulletin 86, "Windbreaks," by C. G. Bates. It is therefore unnecessary to consider it here.

For reservoir and watershed protection white pine has already been extensively planted throughout New England. Like other conifers, it is better than hardwoods for the purpose because its leaves do not readily blow into the reservoirs. Its rapid and hardy growth make it generally preferable to most other conifers wherever conditions are favorable for its growth.

Besides protection, the stand may be useful in producing timber. Where the double purpose is sought the pine should be grown in pure, even-aged stands. The rotation may, however, be much longer than that used when timber alone is desired. The shelterwood method, followed by ample disengagement cuttings and the planting of stock on bare areas, can be used to advantage.

PLANTING AND SOWING WHITE PINE.[1]

Throughout most of its range white pine is probably the most popular native tree for forest planting. In New England it has been set out chiefly for scenic effect and for reservoir protection, although there are a number of plantations for the commercial production of timber. Since one of the chief things to be considered in raising white pine is the cost of establishing the stand, it is necessary to compare the efficiency of different methods and to determine the cost involved in each.

White pine stands may be established artificially either by planting seedlings or by sowing seed directly on the area. Under most conditions planting offers the best chance for success, and is, in the long run, the cheaper method. Occasionally, however, favorable climatic and soil conditions insure the growth of excellent stands from artificially sown seed. Seeding is especially worthy of consideration where large areas have to be planted up in a limited time, but the method should never be used without first experimenting on small areas to determine its probable success.

There are a number of methods of planting and sowing which have proved successful under different conditions of site and labor. Whether an area is to be planted or sowed, the first step is to procure the seed.

[1] For a full discussion of methods and costs of artificial forestation see Forest Service Bulletin 76, "How to Grow and Plant Conifers in the Northeastern States," and Bulletin 98, "Reforestation on the National Forests."

OBTAINING THE SEED.

Seed may be procured either by purchase from dealers or by collecting the cones in the woods. If seeds are purchased, the dealer should be required first to furnish a sample and to guarantee that the remainder of the seed will be equal to it in quality. The sample should be tested by cutting open 100 or 200 with a sharp knife and observing the percentage of those which are plump, well-filled, and oily—indications of good quality. While the actual germination per cent will be lower than that shown by the cutting test, the result will be a reasonably safe guide to the quality of the seed. Seed is likely to be better and cheaper during years of abundant production than during off years. Wherever possible the climate of the region where the seed is collected should be like that in the region where it is used.

White-pine seed ordinarily costs from \$1.40 to \$4 per pound, averaging about \$2.25. The cost of collecting seed, however, is relatively low, ranging from 60 cents to \$2.50 per pound, and, if properly done, better seed can be secured than by purchase. Where the area to be planted or sown is large and cones can be obtained in quantities from a near-by forest, it may be advisable to collect the seed.

The cones should be collected just before they open, which is usually during the first half of September, or perhaps a week earlier or later, depending upon the season and the situation. In the open and on south exposures cones mature earlier than in dense woods or on north slopes. When some of the cones begin to turn brown it is usually time to collect them. Cones may be secured from trees felled in logging or, if lumbering is not going on, by climbing the trees and picking them off. Trees growing in the open bear more cones and are easier to climb than those in dense stands. Cones may sometimes be obtained from squirrels' hoards.

As soon as collected, or even while collection is in progress, the cones should be dried and the seeds extracted. Since rain or damp weather will handicap this work, it is best done indoors. If the weather is clear, however, the cones may be dried by spreading them out thinly on canvas sheets in the sun and wind. The sheets should be made into bundles at night or a loose flap thrown over the cones. If the weather becomes damp, drying should be completed indoors.

When the cones are dried indoors a room should be selected in which there is a free circulation of air, but which rodents and birds can not enter. The cones should be placed in racks made of laths laid parallel one-half inch apart, fastened at each end by laths nailed above and below. The racks, built like shelves one above the other about 18 inches apart on notched uprights fastened to the floor and ceiling, should be 4 feet square, which would give them a capacity of 2½ bushels of cones, though drying will be facilitated if a less amount is used. The cones should be stirred frequently, and those which appear shrunken or wilted removed. Progress in drying will be indicated by the opening of the cones, announced by an audible pop or snap. When preliminary drying is completed the cones should be taken to a second room to be fully opened by artificial heat. This room, which must be reasonably air-tight, should contain a stove in one corner, with two pipes extending from a double elbow across the room and level with the top of the stove. Above the pipes should be tiers of wooden trays with bottoms of wire mosquito netting arranged one above the other, so that the heat will rise through them. A temperature of about 100° F. may be maintained in the room without injury to the seed. Before being placed in the trays, however, the cones should be screened, in order that no loose seed will be subjected to the heat. When the cones nearest the stovepipe are dry they should be removed, and the upper trays dropped down, while the empty ones should be refilled and inserted above.

When nearly all are open the cones should be removed from the drying room, thrashed thoroughly with a flail, and screened. The screen should have a $\frac{1}{2}$-inch mesh and a frame about 6 feet long by 3 feet wide. The seeds and débris which fall through it should then be rubbed through a final screen with a mesh of about $\frac{1}{6}$ inch. This will break off the seed wings and remove the larger particles of dirt and pitch. The seeds and finer particles which pass through the last screen should then be run through a fanning mill, which will remove all the wings and dirt and leave the clean seed ready to be sowed or stored. Each bushel of cones will yield from one-half pound to a pound of clean seed, running from 26,000 to 30,000 seeds to the pound.

Seeds may be stored over winter by inclosing them in a paper or cloth bag (not oiled) and suspending them in a cool, dry room with a free circulation of air. Cellars and stables are not good storage places. If thoroughly dry, seeds may also be stored in large, tight tin cans or in bottles, preferably in an unheated building.

THE FOREST NURSERY.

Where the area to be planted is small, it is better to purchase planting stock from dealers than to incur the trouble and expense of nursery culture. If, however, the area is so large that planting operations will extend over several years, stock may be raised at a considerable saving.

The size of the nursery depends upon the number of plants to be produced each year and the length of time the young trees are to be left in the beds. In most planting operations stock 3 years old should be used. To enable them to develop a strong and compact root system the seedlings should be transplanted when 2 years old from the beds in which the seed germinated to rows in another part of the nursery, where they should remain a year before being set out in the field. Such stock is called "2–1" transplants. To plant 10 acres a year would call for an output of not over 15,000 of these, and the total nursery area required would be about 10 or 12 square rods.

The nursery should, if possible, be close to the planting site. A good, well-drained soil is essential. This should be preferably a rich sandy loam, and the seed beds, at least, should be heavily fertilized with well-rotted barn manure. A northern exposure is best, since it offers the least chance of damage from frost heaving and from drying winds. Water should be available for the stock in hot weather, and the nursery should be well fenced, preferably with woven wire.

To accommodate 15,000 seedlings two seed beds 12 feet long and 4 feet wide will usually be sufficient. It is well, however, to have an extra bed to provide against possible loss of seedlings from disease, frost heaving, or drought. The beds should run east and west, so that the shade from the lath frames over them will be well distributed through the day. In constructing the beds the ground, after being fertilized, should be well spaded, cleared of all débris, and the earth pulverized. Beds should be raised about 4 inches above the general surface of the ground, with their centers slightly higher than their edges, to secure good drainage.

As a protection against birds and small rodents the beds should be inclosed in wire netting of small mesh; one-third-inch mesh is the best. The netting should be cut in 6-inch widths and nailed on frames placed around the beds. The lower strip of the frame should be covered with earth to prevent entrance from beneath it. A cover of the same wire netting should fit snugly on the side frames.

When the wire screen is being fitted to the beds it is well to prepare lath shade frames, which will be needed as soon as the seedlings appear. These consist of frames made of 2 by 2 inch pine strips with 4-foot crosspieces at each end, across the top of which laths are nailed at intervals equal to their width.

When the wire screen is in place the bed should be thoroughly soaked with water to a depth of 6 inches and firmed and smoothed with a spade, roller, or board. It is then ready for the seed, which may be sown either broadcast or in drills. In many ways the former method is best. If the seed is good, about 10 ounces (17,500 seeds) should be sown on each bed, but if the quality is poor a correspondingly larger amount will be needed. Seed should be pressed into the soil with a clean, smooth hoe or spade. A layer of fine soil, not over one-eighth inch deep, should then be spread over the beds. A coal-ash sieve, or one with a mesh of about one-fourth inch, should be used. Beds should be sprinkled until the seeds germinate, and should be covered with both the wire and lath screens. The open spaces in the latter should be filled in with loose laths, while light and air should be further excluded from the beds by tacking some light covering, like building paper, around the frames and banking earth about the bases.

Seed should not be sown in the beds until after the frost is out of the ground and all danger of freezing weather is past. Sowing may be done when garden vegetables are planted, but if delayed until too late the tender seedlings may succumb to heat. It is better, however, to sow too late than too early. Germination is normally very slow, and two or three months may elapse before it is completed. From every pound of fertile seed about 12,000 plants may be expected.

When the germination period is past the beds should be examined from time to time, and a few days after the seedlings have begun to appear the paper and the loose laths should be removed from the shade screens. Unless this is done there is danger of poor development and damping-off. The latter is a very dangerous fungus disease[1] which may destroy all the seedlings in a bed during the first year. It develops most rapidly in moist and shady places and in wet soil. Good preventives are thorough ventilation and drying out. For this reason the shade frames should be entirely removed from the beds on overcast or damp days. The wire screen should be left on at all times except when work is being done.

In dry weather the beds should be sprinkled lightly about sunset. The partial shade given by the lath frames is necessary only during the summer of the first year, during hot, dry days, to protect the tender seedlings from sun scald and wilting and the beds from drying out. While the frames should be used also to protect the seedlings from heavy rains, they should be removed afterwards to permit the soil to dry out.

Toward fall the shade frames should be removed permanently, in order that the seedlings may harden up for the winter. The wire screens may also be removed at that time. After the first fall of snow the seedlings should be covered with a thickness of burlap, which should be left on the beds until the following spring.

Little care is necessary during the second summer other than to keep weeds out and supply the seedlings with water during very dry weather. Ordinarily no protection against birds and rodents is needed, nor is it necessary to cover the 2-year old seedlings for the winter.

To secure 2–1 stock the seedlings should be transplanted in the spring of the third year. In doing this care should be taken not to injure the roots or stems. The spade should be forced deep enough into the ground to get to the bottom of the roots, and the soil which adheres should be carefully shaken off. The seedlings should either be

---

[1] Suggestions for the prevention of damping-off are given in Bureau of Plant Industry Circular 4, "The Treatment of Damping-off in Coniferous Seedlings," by Dr. Perley Spaulding.

transplanted at once or their roots protected by a cover of fresh earth. Even a brief exposure of the roots to sun and air will kill the plants. A transplant bed 4 by 40 feet in size will hold about 2,000 transplants, arranged in transverse rows 6 inches apart with the plants 2 inches apart in the row. With reasonable care in transplanting, each bed should furnish 1,500 young trees. If the transplants are to be kept 2 years in the beds, the space between the plants in the rows should be doubled, thus reducing the capacity of the bed to 1,000, with probably 750 seedlings available for planting. The soil in the transplant bed need not be as rich as that in the seedling beds. Unless the transplant beds are well drained, however, they should be raised about 4 inches above the paths, with not too steeply sloping edges. The seedlings should be carried to the transplant bed in a wheelbarrow, basket, or broad, flat frame, with their roots lightly covered with loose, fresh earth. The transplant beds themselves should be well watered before the plants are placed in them. To save time and insure regular spacing of the plants a transplant board is useful. One employed with success by C. R. Pettis, State Forester of New York, is described as follows: [1]

This board should be 4 feet 3 inches long and 5½ inches wide, with notches cut on both edges of the top side, either 2 or 4 inches apart, according to the required distance between plants in the row, but the first notch should be 3 inches from one end and the notches exactly opposite on both sides of the board. The board is held in place by two sharpened pins set in the board and projecting from the under side. The planting board is laid crosswise of the bed so that the first row of trees will be set on the line marking the end of the bed, and one end of the board will be against the string that marks the side of the bed. After this first row is planted the board is moved back, or toward the planters, and the far side of the board placed against the row of seedlings already planted and one end against the string as before. One plant is set at each notch and the work proceeds in this manner until the bed is filled. If care is taken to keep the end of the board even with the string along the side of the bed the plants in each bed will be in straight rows both ways. It costs no more to have this uniform arrangement and is an advantage in every way, especially since it aids cultivation and gives each tree equal advantage.

Two men to a transplant board, one at each end, can work to best advantage, and doing the work thoroughly should set out 500 plants per hour. A long, narrow trowel is the best tool to use, and care should be taken to make the holes sufficiently deep for the root system. Care must also be taken to put the roots into the hole in proper position and to see that the plants are set in the ground at the same depth that they were in the seed bed. The earth should be thoroughly packed around the roots. The foreman can easily see if the laborer has planted the seedlings at the proper depth, and by pulling can find out whether they are set firmly and are tight in the ground. It requires constant supervision to see that the soil around the roots has been packed properly. As soon as the planting is completed the bed should be leveled and the nursery cleaned up.

[1] See Forest Service Bulletin 76, "How to Grow and Plant Conifers in the Northeastern States." Similar planting boards are described and illustrated in the following articles: "New Tools for Transplanting Conifers," by William H. Mast, Forestry Quarterly, Vol. X, No. 1; and "The Yale Transplant Board," by J. W. Toumey, Forestry Quarterly, vol. IX, No. 4.

Transplant beds need thorough weeding during the summer, which can best be done when the ground is moist. The transplants should be watered well when set out, and again from time to time during the first week or so. After that, however, they need not be watered except during very dry weather. They need no covering during winter.

Two-year seedlings, 1 year transplanted, are probably best for cut-over lands with a thin ground cover, or old fields covered with low growth or grass. Younger stock, however, may sometimes be used in such places, and where this is possible the expense involved in the larger nursery and longer cultural operations can be saved. For example, a portion of the seedlings are sometimes removed from the seed-bed the spring after the seeds are sown and are transplanted after one year, and then set out in the field. Those left may be planted along with the 1–1 transplants directly in the field or they may be transplanted one year before being set out. In the latter case the final stock will consist of 1–2 and 2–1 transplants. For planting in situations where the ground cover is at all dense 2-year old seedlings, 2 or even 3 years transplanted, should be used.

PLANTING.

Seedlings for planting may be raised in the nursery, as just described, purchased from dealers,[1] or dug up in the woods. The cost of producing 10,000 or 20,000 3-year-old transplants every year will probably be close to $4 per thousand, and when good stock of the same age can be secured at a price not too far above this, it is usually better, in small operations, to purchase it. Wild seedlings may be used, but as a rule their root systems are straggling, and the plants lack the resistant qualities of transplants.

Planting is best done in the spring, as soon as the frost is out of the ground and before the buds of the young trees have begun to grow. Since the time is thus limited to from four to six weeks, planting should take precedence over nursery work.

If the planting site is near the nursery, the stock may be carried to it in the same way as from the seed to the transplant bed. Even greater care should be used, however, to prevent the roots from becoming the least bit dry. When the stock arrives at the planting site it should immediately be "heeled-in." If it is purchased stock and comes bundled, the bundles should be untied and loosened. Heeling-in consists in placing the plants in a thin layer along the sloping side of a ditch dug slightly deeper than the length of the

[1] A dangerous disease of white pine, the "blister rust," has recently been introduced into American nurseries from Europe. When buying stock for planting, the seller should be required to guarantee it to be free from this disease. The blister rust is discussed in detail in Bureau of Plant Industry Bulletin 206, "The Blister Rust of White Pine," by Dr. Perley Spaulding.

roots. The roots of the young plants should be carefully spread out and covered with fresh or moist earth, the ditch filled, and the soil packed by tramping and thoroughly soaked with water. When the planting is not to be done at once, the heeled-in stock should be shaded in some way, as by spreading boughs over it. The plants should be carried to their final destination in a basket or pail with their roots surrounded by a quantity of damp sphagnum moss or by pieces of wet burlap. The importance of keeping the roots moist and protected from the air can not be too strongly emphasized. Even a few minutes exposure will kill the plants, especially on hot, dry days. In the past it has been customary to transport the plants to the field in pails with their roots immersed in a puddle of clay or loam and water. While excellent results have been obtained by this means, it is now believed that puddling causes many of the fine rootlets to stick together and to interfere with each other, so that the death of many plants, especially in dry situations, can probably be traced to this practice. Fresh but not wet sphagnum moss is a convenient substitute and makes it possible to spread out the root fibers when the seedlings are planted. When possible, planting should be done on sultry or overcast days.

In planting, the men work in pairs, one man digging holes and the other setting the trees. The mattock is usually preferred to the spade for this work. The holes should be large enough to give room for the roots without crowding, and, especially on light soils, the plants should be placed slightly deeper than they were in the nursery. When making the hole, it is well to cut off and remove a thin slice of sod in order to avoid immediate competition of grass roots. The roots of the plants should be spread out and placed in as nearly a normal position as possible. This can be accomplished by lowering the plant until the base of the stem is close to the bottom of the hole and the roots are spread out horizontally. Fresh earth is then thrown in with the free hand. At the same time the plant is raised with the other hand until the base of the stem almost reaches the surface level. Instead of tramping the earth down solidly from above, it should be compressed from the sides by putting both hands simultaneously into the loose earth 2 or 3 inches on either side of the stem and compressing the closed fists strongly toward the plant. The empty spaces are then filled with earth, which is pressed firmly downward with the closed fists, care being used not to apply the pressure too near the central earth mass. Loose earth should then be thrown over the surface.[1] While this method is at first a little slow, it can be carried on with considerable speed after some practice.

[1] This method, devised and carried out with great success by the Belgian forester, Morris Kozesnik, is described and illustrated in the Proceedings of the Society of American Foresters, vol. IV, No. 2.

Where the soil and climatic conditions especially favor the growth of seedlings, the less expensive method of "slit planting" may be used. In this the roots of the seedling are dropped into a slit in the soil made by inserting a spade and slightly working it forward or backward. The soil is then packed about the roots by reinserting the spade 2 or 3 inches from the plant and closing the previous slit. The soil is then firmly pressed down with the foot. This method is a very rapid one, but the roots are left in a crowded and unnatural position, which may for years interfere with the thrift of the plant.

The number of trees which can be set out per day varies with the nature of the ground cover, the texture of the soil, the character of the labor employed, and the degree of care exercised in the work. On fresh loamy or sandy soils, without a low herbaceous ground cover, two capable workmen should be able to set out 1,000 of the 2–1 transplants a day. With unfavorable conditions, as when the ground is full of tough roots, the same men might plant only 500 seedlings.

The most common and probably the best spacing for white-pine transplants is 6 by 6 feet. In especially favorable situations, where growth will be rapid, a spacing of 8 by 8 feet may be used, while in less favorable ones the plants should be closer together, either 5 by 5 feet or 4 by 4 feet. The number of plants per acre spaced at different distances is shown in Table 18. Where pruning is to be practiced, a spacing of 10 by 10 feet, or 12 by 12 feet, has been recommended.

Table 18.—*Number of trees required to plant an acre, using rectangular method of spacing.*

Distance between the rows.	Number of trees when distance apart in the row is—				
	4 feet.	5 feet.	6 feet.	7 feet.	8 feet.
Feet.					
4	2,722	....	....	....	....
5	2,178	1,742	....	....	....
6	1,815	1,452	1,210	....	....
7	1,556	1,244	1,037	888	....
8	1,361	1,089	907	777	680

The cost of planting per thousand plants varies with the same factors which influence the daily rate of planting. The cost per acre varies with these and also with the number of seedlings planted per acre. Tables 19 and 20 give the cost per thousand and per acre, respectively, of planting stock costing $3, $4, and $6 per thousand when the average planting rate per man is 300, 500, and 600 plants per day, with different daily wage rates. The average planting rate is based on the total time consumed in the work, including digging up or unpacking transplants, carrying from nursery to field, heeling-in, etc.

TABLE 19.—*Total planting cost per thousand plants for planting stock of different values.*

Number planted per man per day.	Daily wage rate per man	Labor cost per thousand.	Total cost per thousand of stock and labor.		
			Planting stock $3 per thousand.	Planting stock $4 per thousand.	Planting stock $6 per thousand.
300	$1.50	$5.00	$8.00	$9.00	$11.00
	2.00	6.67	9.67	10.67	12.67
500	1.50	3.00	6.00	7.00	9.00
	2.00	4.00	7.00	8.00	10.00
600	1.50	2.50	5.00	6.50	8.50
	2.00	3.33	6.33	7.33	9.33

TABLE 20.—*Total planting cost per acre under different conditions.*

Number planted per man per day.	Daily wage rate per man.	Cost of planting stock per thousand.								
		Spacing 8 by 8 feet.			Spacing 6 by 6 feet.			Spacing 4 by 4 feet.		
		$3	$4	$6	$3	$4	$6	$3	$4	$6
300	$1.50	$5.44	$6.12	$7.48	$9.68	$10.89	$13.31	$21.78	$24.50	$29.94
	2.00	6.58	7.26	8.62	11.70	12.91	15.33	26.32	29.04	34.49
500	1.50	4.08	4.76	6.12	7.26	8.47	10.89	16.33	19.05	24.50
	2.00	4.76	5.44	6.80	8.47	9.68	12.10	19.05	21.78	27.22
600	1.50	3.40	4.42	5.78	6.05	7.87	10.29	13.61	17.69	23.14
	2.00	4.30	4.98	6.34	7.66	8.87	11.29	17.23	19.95	25.40

The tables bring out the fact that the spacing, more than any other factor, influences the acre cost of planting. The spacing of 4 by 4 feet requires so many trees per acre that, as a rule, its cost is prohibitive. The 6 by 6 plantation will vary in cost between $6 and $13 per acre, although when all incidental expenses of planting are figured it may in some cases exceed $15. A spacing of 8 by 8 feet is very desirable from the standpoint of cost, and on good soils with cool, moist exposure, the rapid growth of the trees may fully warrant it. In such cases the first thinning may be made later than with other spacings. While with the wide spacing the branches may grow a trifle larger, they will persist no more tenaciously than when the stand is denser. The saving in the initial cost may be later expended to good advantage in pruning. Moreover, in a widely spaced plantation there is room for the development of desirable broadleaf trees between the pines.

DIRECT SEEDING.

Under average conditions artificial sowing is less likely to be successful than planting, and in a number of cases has resulted in complete failure. There are, of course, notable exceptions, such as the Shaker plantation in north central Connecticut, where a very dense forest resulted from the broadcast sowing of pine seed along with rye. One crop of rye was reaped and the land then abandoned to the pine.

While the initial expense of sowing may sometimes be less than that of planting, it is often greater, and the stand, even if moderately successful, will usually contain openings which must be planted up if a fully stocked stand is desired. In the long run the sowed stand may prove considerably more costly and at the same time inferior to the planted one. Sowing, however, is a relatively easy method of reproduction, and is the only way in which very large areas can be economically covered in a single season.

There are three methods of sowing seed direct: (1) broadcasting over the whole area, (2) sowing in strips, and (3) sowing in seed spots.

Broadcast Sowing.

Ordinarily, broadcast sowing offers little chance of success, except when the ground has been cultivated or burned over, or the seed raked in after sowing, for not only must there be a sufficient amount of moisture for germination, but the seedling must quickly get its rootlets into mineral soil. It is best to sow broadcast except where conditions are especially favorable, as when there is a very light ground cover partially exposing the mineral soil. Conditions such as these may be found on burned-over areas coming up to aspen, from which fire has removed part of the grass and litter, and shade is afforded the pine seedlings in early youth by the aspen trees. Ground covered with leaves of broadleaf trees is not a suitable site for broadcasting, since the leaves either prevent the seed from reaching the soil or smother the seedlings after they germinate. Sloping ground, where there is usually the least litter, with a north or east aspect, ordinarily offers the best site for broadcasting. It is on recently cultivated land, however, that broadcast sowing has been most successful. Here also the sowing can be combined cheaply with crop raising.

Until white-pine seed becomes cheaper, however, broadcast sowing is hardly justified from a financial standpoint. Five pounds of seed are necessary to broadcast an acre. With the price of seed at $2.25 per pound (cheaper at wholesale), the initial cost of sowing an acre will be $11.25. Results obtained in actual practice vary from total failure to a stand of several thousand seedlings per acre. Success depends chiefly upon whether the ground is properly prepared. A pound of seed sown in a nursery bed will produce from 10,000 to 15,000 seedlings, and the expense of producing and planting on an acre 1,210 two-year-old seedlings (6 by 6 spacing) will cost from $7 to $15, with a reasonable assurance of 80 per cent survival.

Sowing in Strips.

Under the strip method strips 6 to 8 feet wide are sown, gridironing the tract with blank spaces from 6 to 8 feet wide between. This method is cheaper than broadcasting since less seed is required per acre.

Sowing in Seed Spots.

The method of sowing in seed spots consists in sowing the seed in prepared spots at regular intervals. The sod is removed from a small spot, commonly about a foot in diameter, and a seed bed prepared in which from 5 to 15 seeds are planted. The work can be done with a hoe, and the planters kept in line by flags. Spots where the seed fails to germinate should be filled in the following year by transplanting from spots which have produced groups of seedlings. Conditions favorable for seed-spot sowing are the same as those for planting two-year-old seedlings; namely, where there is a light ground cover, as on old pasture land. Under the shade of hardwood sprouts or on moist ground there is little chance for success.

With the seed-spot method one man should sow an acre a day and use 1 pound of seed. With labor at $1.75 a day and seed at $2.25 a pound, the initial cost will be $4 per acre, with a cost for filling in the gaps to be added later on. In New York State a careful record of the expenditures for seed-spot planting indicates that $10 per acre is the average cost.[1]

Protection from Rodents.[2]

A large source of loss when seed is planted directly in the field comes about through its destruction by small rodents. To prevent this, small amounts of grain soaked in a solution of strychnia should be deposited over the area in the spring, some time in advance of the sowing. A formula for poisoning chipmunks, recommended by the Biological Survey, which has given good results, is the following:

Strychnia sulphate	1 ounce.
Saccharin	1 teaspoonful.
Gloss, or laundry starch	½ cupful.
Water	1 quart.
Barley	20 pounds.

Where mice as well as chipmunks are prevalent the following formula has proved effective:

Strychnia (alkaloid or sulphate)	1 ounce.
Saccharin	1 teaspoonful.
Melted tallow	1 pint.
Wheat	16 quarts.

[1] C. R. Pettis, Fifteenth Annual Report Forest, Fish, and Game Commission, State of New York.

[2] This subject is fully discussed in Biological Survey Circular 78, "Seed Eating Mammals in Relation to Reforestation," and in Forest Service Bulletin 98, "Reforestation on the National Forests."

The wheat should be warmed in a metal saucepan or similar receptacle and the saccharin and strychnia pulverized and sprinkled over it. The melted tallow should then be poured in, and the mixture stirred until every wheat kernel is coated.

In depositing the poisoned grain it must be put out of the reach of birds. This can be done by placing it in cavities among small piles of stones or under roots or logs, or in burrows of animals. If this is not practicable the grain can be covered with pieces of bark, boards, or flat stones, with a low runway left beneath. Barley is usually attractive to rodents and is at the same time the grain least relished by birds.

PROTECTION.

FIRE.[1]

Unlike loblolly pine of the South, or the red pine with which it is often associated, white pine has a thin bark during the first 30 or 50 years of its life, which affords but slight protection from fire. Young growth, with its thin bark and delicate foliage, is usually killed at once by fires which would do little damage to thick-barked trees. When white pine has reached an age of from 40 to 60 years, however, and has formed a thick, corky bark, it is comparatively safe from direct injury by surface fires. Yet if the fire reaches the crown and scorches the branches the tree is certain to die. Young pines also are often killed in this way. Besides its direct damage, fire offers a way for insects and fungi to enter the trees.

Measures usually included under fire protection aim (1) to prevent fires from starting, (2) to detect fires as soon as possible after they start, and (3) to extinguish them when once started in the shortest possible time.

Briefly, fire prevention consists in (1) suitable legislation regarding fires, (2) destroying and rendering less dangerous inflammable material, and (3) constructing efficient fire lines to prevent the spread of flames.

Most of the Eastern States already have excellent fire laws, which when supported by an educated public sentiment and properly inforced tend to reduce the fire risk to the minimum. These laws usually provide against lighting fires during danger seasons, and impose penalties for damage from fire which may be allowed to escape at any time. The laws usually contain special provision for the use of spark arresters on locomotives and of oil instead of coal for fuel in regions where the risk is great.

[1] For a full discussion of forest fires and their prevention, see Forest Service Bulletin 82, "Protection of Forests from Fire," by Henry S. Graves; also Forest Service Bulletins 111, "Lightning in Relation to Forest Fires," and 117, "Forest Fires; Their Causes, Extent, and Effects, with a Summary of Recorded Destruction and Loss," by Fred G. Plummer.

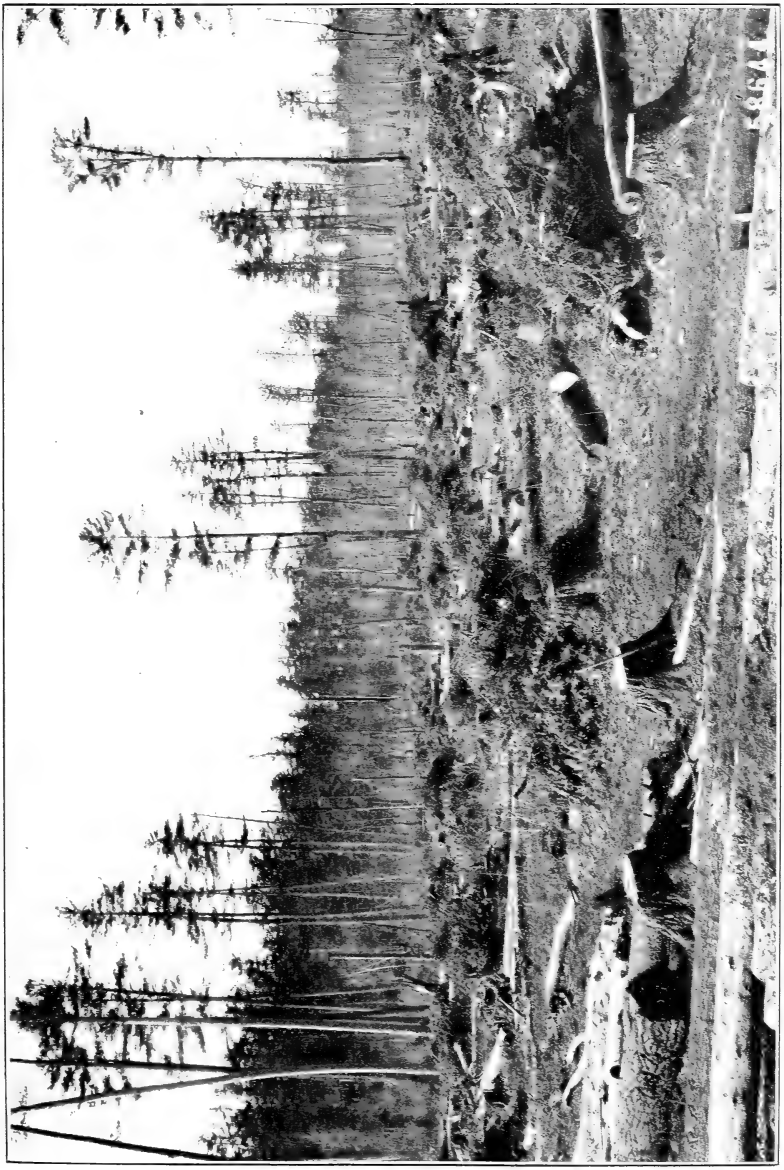
The disposal of slash is important as a preventive measure. The best time to destroy brush or débris is while logging is in progress. With the aid of one extra swamper the burning of brush can be cheaply and effectively done by the logging crew. The best time to burn brush is during a wet season, preferably in winter when snow is on the ground. The cost of burning depends upon the character of the stand and the cost and efficiency of labor. Wide-topped trees, the type known as "cabbage pines," have heavy crowns and large limbs, which cost more per thousand board feet to burn than the brush from smaller crowned trees grown in pure, fully stocked stands. In mixed stands of white pine and other species, the burning of white-pine slash is more expensive than in pure stands. In mixed stands of red and white pine, in the Lake States, brush has been disposed of while the logging is in progress for 12 cents per thousand board feet. In many cases, however, it will cost much more than this.

When logging is done in a dry season the brush should be piled when the trees are cut, but not burned until moister conditions prevail. In piling, the tops should be thrown to the center of the piles and the smaller branches placed at the bottom, with successively larger material laid above. This makes a compact pile, easy to burn. The size of the piles will depend upon the amount of material to be disposed of and the available space. Small piles are safer than large ones, a convenient size being 10 feet across and 6 feet high. The piles should not be within 20 feet of standing trees or placed in a way to obstruct the skidding of logs. In general, the cost of piling and burning white-pine slash will probably range from 25 to 50 cents per thousand board feet of lumber cut.

The slash should not be burned in windrows, since unless the weather and moisture conditions are favorable there is danger of starting a general conflagration. Often, moreover, the windrows cover a large percentage of the total area, and when they are burned the greater part of the seed which has fallen during logging will be destroyed.

While the scattering of slash is not advisable where there is danger from fire, it may, wherever conditions permit, be made to serve an important function by protecting the soil and small seedlings from drought and frost. In scattering slash, however, no tops should be left propped up on the ground by their side branches. All branches should be lopped and the brush made to lie flat on the ground. In close stands, where burning is impracticable, scattering is the best means of disposing of slash. It is also perhaps the best method in moist situations where the branches will decay rapidly.

For the prevention of fire on comparatively small tracts a simple system of fire lines, supplemented by patrol at intervals during the danger season, is probably sufficient. On large tracts a system



BRUSH PILED FOR BURNING; CLEAR CUTTING, LEAVING 5 PER CENT OF THE STAND FOR SEED TREES. MINNESOTA.

of roads and trails is exceedingly useful and in many cases essential, since they serve as fire lines and at the same time afford easy access to any part of the area. A road only 6 feet wide, from which all litter and vegetation have been removed, can be made an effective barrier against a severe ground fire, while a single furrow of earth or a cleared trail will often check a surface or grass fire. Where the risk of fire is very great, as in extensive pine forests, or where valuable property is to be protected, special fire lines may have to be constructed. The most effective kind is a fully cleared strip, from which trees, underbrush, and all débris and litter have been removed down to the mineral soil. Ordinarily a width of from 6 to 15 feet is sufficient, though sometimes a greater width may be necessary. The cost of constructing a fire line for second-growth woodlands ranges from $30 to $50 a mile.

Existing roads and trails can, of course, serve as fire lines. To be really effective, however, they must be cleared of all underbrush and débris. In addition, fire lines should be established at strategic points, such as boundary lines and along hill crests. Especially dangerous points, such as along a railroad or where old slashings are next to young reproduction of valuable timber, should also be protected by special fire lines. In the Northeastern States, where the woodlands are in small blocks broken by many roads and trails and numerous houses, the presence of a forest fire is soon detected. The farmer can act as his own guard, and by proper care in clearing out his roads and disposing of his brush make his woodlot comparatively safe.

For observing wide stretches of uninhabited woodland, forest-fire lookout stations on elevated points have been established in several of the States with good results. The watchman in charge is provided with a map of the surrounding country, a telescope to detect a fire, and a range finder to locate its position. As soon as a fire is observed he telephones for aid. During the dry season, from April 1 to October 1, a patrol system is very essential for the protection of wide stretches of sparsely settled country.

An effective fire-fighting outfit should include shovels, rakes, grub hoes, axes, ropes, and collapsible pails. The implements should be kept in a convenient place ready for immediate use.

The various methods of fighting fires have been developed according to the needs of a particular locality. For checking ground fires which smoulder and burn stubbornly where there are large accumulations of duff, the digging of trenches with shovels or grub hoes has been found very effective. In sandy land, free from rocks, sand may be used effectively in extinguishing fire. Loose loam is also good for the purpose, though not as effective as sand, but heavy soil that forms clods is of little value. Some surface fires in dry leaf litter or in short grass among scattered tree growth may be beaten out with gunny sacks, green branches, or some similar article. Chemical extinguishers are useful wherever available. Where the woodland is much broken up by roads, the fire-fighting apparatus may be carried in a light, four-wheeled wagon. Such an outfit is especially useful in well-settled regions where fire endangers buildings.

A crown fire, that is, one burning in the tops of the trees, is the most serious. It is always accompanied by surface fires. An ordinary crown fire will jump a wide fire line, and has often been known to cross wide rivers. Under such circumstances back-firing becomes absolutely necessary. It can also be done where other methods of fire fighting can not be used, or where they fail to stop a fire. It should, however, be a last resource.

STOCK.

A pine forest is less liable to injury from cattle than is one composed of deciduous trees. Old pastures often grow up to a fair stand of pine even while being grazed, cattle preferring the broadleaf species. If it is desired to raise timber, however, cattle should be excluded for four or five years, or until the young growth obtains a good start, since they are certain to do more or less injury to the growing trees.

White pine when injured shows considerable powers of recuperation, as exhibited in the ready reestablishment of a broken leader and the healing of wounds. In the latter case the prolific resin exudations assist by keeping out water and fungi.

WHITE PINE WEEVIL.

There are a number of insect and fungous enemies of white pine which may do more or less damage to the trees. This bulletin treats briefly of but one of these sources of injury, the white pine weevil,[1] *Pissodes strobi*, an insect which does a good deal of damage to white pine practically throughout its range, but especially in the East. The weevil is a reddish-brown beetle, about one-quarter of an inch in length, which, like all weevils, has a proboscis or snout. It always attacks the terminal shoot or leader of the tree and kills back the growth of one or two years. Though a new leader begins to develop the next year, through one of the side branches assuming a vertical position, there remains a more or less pronounced crook. Crooked branches, when of fair size, often saw out surprisingly large amounts of round-edged box board lumber, but the loss in badly infested stands is nevertheless great. The damage shortens the length of boards which can be sawed out and, of course, interferes with subsequent growth in quality. This is especially the case when, as often happens, the same trees are repeatedly attacked.

[1] The white pine weevil, its habits and methods of control, are described in Circular No. 90, of the Bureau of Entomology, by A. D. Hopkins.

According to Dr. Hopkins, the adult overwintered beetles are active during the month of May, and the eggs are deposited in the bark of the terminal of the preceding year's growth. Small whitish grubs hatch from these eggs, feed on the inner bark, and thus cause the death of the terminal. When the grubs are full grown they transform to pupæ early in July in chip cocoons in the outer wood or pith of the terminal, and the adults will begin to emerge from the terminals during the last week in July, and practically all will be out by the 15th of September.

The terminals which are infested with the medium to maturing stages of the weevil are easily recognized during the latter part of June and first part of July by the wilting of the new terminal and branches on the last year's terminals, and this is the time the terminals should be removed in order to destroy the brood.

Weevil damage is most common, and always most serious, in trees less than 30 feet high. Protective measures must be undertaken, therefore, when the stand is young. Whenever an infestation appears all the pine tops which show it should be cut off during June and July, before the beetles have escaped. These can be burned, but since they often contain minute insect parasites which are themselves valuable agents in resisting the increase of the weevils, it is best to treat them according to the method suggested by Dr. A. D. Hopkins, of the Bureau of Entomology. This consists in placing the infested tops in a tight box, barrel, or preferably a metal can with but one opening covered with ordinary fly-screen netting. This permits the escape of the small parasites, but confines the weevils. The receptacle, if of wood, should be examined from time to time to see that no weather checks or cracks develop which would allow the weevils to escape. It will take more than one season to exterminate weevils should they appear, and young stands should, wherever possible, be examined every year during the months of June and July.

Occasionally two side branches instead of one will replace the destroyed leader, resulting in a forked tree. To prevent this, all but one side branch of the upper whorl—the thriftiest where there is a difference—should be cut off even with the main stem. Where trees have already started to fork one of the forks should be removed in the same manner.

APPENDIX.

Height Growth in Germany.

Table 21 shows the height growth of white pine in German plantations.

Table 21.—*Height growth of white pine in German plantations.*[1]

Age.	Height.		Age.	Height.	
Years.	*Meters.*	*Feet.*	*Years.*	*Meters.*	*Feet.*
10	3–5	10–16	60	22–24	72–79
20	8–10	26–33	70	25–27	82–89
30	12–14	39–46	80	28–29	92–95
40	16–18	52–59	90	30–31	98–102
50	19–21	62–69	100	32–33	105–108

[1]Hemple und Wilhelm, "Die Bäume und Sträucher des Waldes," pp. 182–187.

Volume Tables.

Table 22 shows the volume in board feet by the Scribner rule for trees of various diameters and height in the Lake States. It is based on measurements of a large number of trees in northern Minnesota, made under the personal supervision of Mr. E. S. Bruce, of the Forest Service. Deductions for defect were made in the field by expert lumbermen.

Table 22.—*Volume in board feet of white pine in northern Minnesota.*

Diameter, breast-high.	Height of tree (feet).											Diameter of top inside bark.	Basis.
	40	50	60	70	80	90	100	110	120	130	140		
	Volume (board feet).												
Inches.												*Inches.*	*Trees.*
8	20	25	30	35	45							6	129
9	25	35	45	50	60							6	220
10	35	45	55	65	75	90						6	248
11	40	55	65	80	95	110	125					7	279
12	50	65	80	95	115	130	150					7	279
13	55	75	95	115	135	155	175					7	271
14	65	90	110	135	155	180	205	230				7	234
15		105	130	155	180	210	235	265				7	246
16		120	150	180	210	245	275	300				7	222
17			170	205	240	280	310	345				8	259
18			190	235	275	315	355	390				8	202
19			215	265	310	355	400	440				8	190
20				295	350	400	450	495	535			9	163
21				330	390	450	500	560	600			9	155
22				370	430	500	560	620	670			9	118
23					480	550	620	680	730			10	106
24					530	610	680	750	810	860	920	10	85
25					590	670	750	820	880	950	1,020	10	99
26					650	730	810	890	960	1,040	1,110	11	68
27					710	800	870	960	1,040	1,130	1,210	11	63
28					780	860	940	1,030	1,120	1,220	1,310	11	56
29						930	1,000	1,100	1,200	1,310	1,410	12	37
30						1,000	1,070	1,180	1,280	1,400	1,510	12	37
31							1,140	1,250	1,370	1,490	1,600	12	36
32							1,210	1,330	1,450	1,570	1,700	12	24
33							1,280	1,400	1,530	1,660	1,790	13	23
34							1,350	1,480	1,610	1,750	1,880	13	15
35							1,420	1,550	1,690	1,830	1,970	13	12
36							1,490	1,630	1,770	1,910	2,060	13	8
37							1,560	1,700	1,850	2,000	2,150	13	4
38							1,630	1,780	1,930	2,080	2,240	13	3
39								1,860	2,020	2,170	2,330	13	6
40								1,940	2,100	2,260	2,420	14	3
Total													3,899

Height of stump, 0.5–3.5 feet. Volume computed by the Scribner rule.

Table 23 shows the volume in board feet by the Doyle-Scribner rule for trees of various diameters and height in the Southern Appalachian Mountains. The figures were compiled under the direction of Walter Mulford.

TABLE 23.—*Volume in board feet of white pine in the Southern Appalachians.*

Diameter, breast-high.	Height of tree (feet).												Diameter of top inside bark.	Basis.
	60	70	80	90	100	110	120	130	140	150	160	170		
	Volume (board feet).[1]													
Inches.													*Inches.*	*Trees.*
12	40	50	60	75									8.5	6
13	60	70	80	95									9.0	2
14	80	90	100	115	135								9.4	7
15	100	110	125	140	160								9.9	12
16	125	135	150	165	185	230							10.2	20
17	155	165	180	195	220	270							10.6	25
18	185	200	215	230	260	310	360						10.9	25
19	225	240	250	270	300	355	410						11.2	37
20	265	280	295	320	350	400	460						11.5	37
21	310	325	345	370	405	455	515	585					11.8	49
22	355	375	395	425	460	510	565	645					12.1	46
23		425	455	485	515	565	625	710	820				12.4	42
24		480	510	540	580	625	685	775	895	1,040			12.7	48
25		535	575	605	645	690	755	845	980	1,140			13.0	53
26		590	640	675	710	755	820	925	1,060	1,240			13.2	65
27		650	710	745	780	825	895	1,010	1,150	1,345			13.5	55
28		710	780	815	850	900	975	1,095	1,250	1,455	1,680		13.7	55
29			855	890	925	975	1,060	1,190	1,350	1,570	1,785		14.0	54
30			930	965	1,005	1,055	1,145	1,290	1,465	1,680	1,895		14.3	52
31			1,010	1,050	1,085	1,140	1,240	1,390	1,585	1,795	2,005		14.6	49
32			1,095	1,130	1,165	1,230	1,335	1,495	1,695	1,910	2,120	2,300	14.8	49
33			1,180	1,220	1,255	1,325	1,445	1,605	1,815	2,035	2,240	2,420	15.1	42
34			1,270	1,315	1,355	1,430	1,560	1,720	1,925	2,155	2,365	2,550	15.4	40
35				1,415	1,460	1,535	1,665	1,835	2,045	2,290	2,505	2,690	15.7	35
36				1,520	1,555	1,655	1,770	1,945	2,175	2,435	2,650	2,855	16.1	32
37					1,660	1,755	1,880	2,065	2,310	2,580	2,810	3,040	16.4	28
38						1,850	1,985	2,185	2,450	2,730	2,980	3,230	16.9	20
39						1,945	2,095	2,315	2,600	2,885	3,165	3,450	17.3	19
40						2,050	2,195	2,430	2,750	3,050	3,345	3,655	17.8	24
Total.														1,028

[1] Volume computed by the Doyle-Scribner rule.

Table 24, based on data collected by Louis Margolin, shows the volume, in board-feet, for trees of various diameters and heights in southern New Hampshire. It is based on the actual mill cut of the trees and therefore runs higher than if it were based on log scale. This should be borne in mind in using the table.

TABLE 24.—*Volume, in board-feet, of second-growth white pine in southern New Hampshire.*

Diameter breast-high.	Height of tree (feet). 30	40	50	60	70	80	90	100	110	120	Basis.
	Volume (board feet).[1]										
Inches.											*Trees.*
5	8	12	15								7
6	13	20	23	27	29						41
7	18	28	34	39	44						75
8	24	36	45	53	62						128
9	32	44	56	69	81	93					156
10	41	53	70	85	102	119	138				177
11		63	84	103	126	147	168				164
12		73	100	125	151	177	200	228	245		146
13		84	117	148	180	210	238	270	293		137
14		95	137	173	210	243	277	312	348		91
15		105	158	200	241	282	321	362	406		61
16			181	230	277	323	370	415	470		88
17			209	261	313	368	421	471	540		70
18			238	297	352	411	475	531	610	688	68
19			270	336	393	460	530	598	682	763	44
20			302	379	436	506	583	660	750	840	35
21				425	480	553	634	720	820	918	23
22					522	597	681	779	887	990	16
23					566	639	727	834	958	1,065	19
24						674	769	889	1,030	1,135	9
25						706	809	942	1,105		12
26						737	846	994	1,180		11
Total											1,578

[1] The volumes are for actual saw cut. Sixty per cent of the lumber sawed was round-edged and 40 per cent squared, 70 per cent 1-inch boards, and 30 per cent 2½-inch plank.

Table 25, from Forest Mensuration of White Pine in Massachusetts, by Harold O. Cook, shows the volume, in board-feet, of second-growth white pine of various diameters and heights in that State. It is based on the actual mill cut of the trees. Tables 26 and 27 show the volume in cubic feet for New Hampshire and Massachusetts, respectively. Table 28 gives volumes in cordwood for Massachusetts.

TABLE 25.—*Volume, in board feet, of second-growth white pine in Massachusetts.*

Diameter breast-high.	Height of tree (feet). 30	40	50	60	70	80	90	100
	Volume (board feet).[1]							
Inches.								
5	10							
6	15	20	30					
7	20	30	40	50	65			
8	25	35	50	65	85			
9	30	45	60	80	105	115		
10	40	55	75	95	125	145		
11		65	90	115	145	170	200	230
12		75	105	135	165	200	230	260
13		85	120	155	190	235	260	295
14		100	140	175	215	265	310	335
15		115	160	200	245	300	340	375
16			180	230	275	335	380	420
17				260	310	370	425	470
18				295	350	410	475	530
19				335	390	455	530	600
20				380	435	505	580	660
21					480	550	635	720
22					520	595	680	780
23					565	640	730	835
24					600	690	780	890
25					645	740	830	940
26							885	995
27							940	

[1] The volumes are for actual saw cut—circular saw—with ¼-inch kerf. The logs were scaled to a minimum top diameter of 4 inches. The stump height was 6 inches.

TABLE 26.—*Volume in cubic feet of second-growth white pine in southern New Hampshire.*[1]

Diameter breast-high.	Height of tree (feet.)										Total basis.
	30	40	50	60	70	80	90	100	110	120	
	Total volume, including bark, stump, and top (cubic feet).										
Inches.											*Trees.*
5	2.3	3.0	3.6								7
6	3.0	4.3	5.1	6.0	6.5						41
7	4.1	5.7	6.9	8.2	9.2						75
8	5.4	7.1	8.8	10.5	12.2	13.9	15.8				128
9	6.9	8.8	10.9	13.0	15.4	17.8	20.2				156
10	8.6	10.5	13.1	15.8	18.9	21.9	25.0				177
11		12.3	15.5	18.7	22.5	26.1	29.9				164
12		14.3	18.0	22.0	26.4	30.8	35.0	40.1	45.9		146
13		16.3	20.7	25.3	30.4	35.4	40.1	45.8	52.0		137
14			23.7	29.1	34.8	40.2	45.8	51.7	58.8		89
15			27.0	33.1	39.2	45.3	51.9	58.0	65.8		61
16			30.7	37.5	44.3	51.0	58.1	65.1	73.7		88
17			35.0	42.3	49.9	57.0	65.1	73.1	82.5		68
18			40.0	47.6	55.5	63.9	72.2	82.0	92.1	104.2	68
19				53.0	60.2	70.9	80.0	91.0	102.1	114.8	43
20					67.1	78.1	88.1	100.2	112.2	125.6	34
21					73.1	85.7	96.7	109.2	122.1	136.3	21
22					79.1	93.1	105.3	118.1	131.7	146.7	16
23						101.0	113.6	127.0	140.5	156.1	18
24						108.6	121.8	135.8	149.8	165.5	8
25						115.8	129.8	144.2	159.0	174.6	12
26						122.7	137.8	153.1	168.5	183.2	11
Total.											1,568

[1] From data collected by Louis Margolin, Forest Service, in cooperation with the State of New Hampshire.

TABLE 27.—*Volume in cubic feet of white pine in Massachusetts.*[1]

Diameter breast-high.	Height of tree (feet).						
	30	40	50	60	70	80	90
	Volume (cubic feet).						
Inches.							
5	1.8						
6	2.6	3.3	4.3				
7	3.4	4.4	6.1	7.7			
8	4.5	6.0	7.8	9.8	12.0		
9	5.9	7.7	10.0	12.0	15.0		
10		9.6	12.0	15.0	17.9	20.9	
11		11.6	14.6	17.9	21.4	24.9	28.7
12		13.9	17.6	21.1	25.3	29.8	33.7
13		16.2	20.4	24.8	29.2	34.7	38.7
14			23.7	28.7	32.5	39.6	43.6
15			26.8	32.6	37.9	44.5	49.5
16			30.5	36.5	42.3	49.8	55.9
17				40.3	47.2	56.7	62.3
18				44.6	52.6	61.5	69.1
19				49.0	57.9	67.8	76.9
20				52.9	63.2	74.7	84.8
21					69.1	82.0	92.6
22					74.9	89.3	101.4
23					81.3	98.1	110.8
24					87.1	104.9	119.0
25					94.0	112.6	128.8

[1] From "Forest Mensuration of White Pine in Massachusetts," by Harold O. Cook. The volumes are for the portion of the tree between a 6-inch stump and a minimum top diameter of 4 inches, and include bark.

TABLE 28.—*Merchantable volume in cords, and number of trees per cord, for white pine in Massachusetts.*[1]

Diameter breast-high.	Height of tree (feet).													
	30		40		50		60		70		80		90	
	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.	Volume per tree.	Trees per cord.
Inches.	*Cords.*	*No.*	*Cords.*	*No.*	*Cords.*	*No.*	*Cords.*	*No.*	*Cords.*	*No.*	*Cords.*	*No.*	*Cords.*	*No.*
5	0.03	33.3												
6	.03	33.3	0.04	25.0	0.05	20.0								
7	.04	25.0	.05	20.0	.07	14.3	0.09	11.1						
8	.05	20.0	.07	14.3	.09	11.1	.11	9.1	0.13	7.7				
9	.07	14.3	.09	11.1	.11	9.1	.13	7.7	.16	6.3				
10			.11	9.1	.13	7.7	.16	6.3	.19	5.3	0.22	4.5		
11			.13	7.7	.16	6.3	.19	5.3	.23	4.3	.26	3.8	0.30	3.3
12			.15	6.7	.19	5.3	.22	4.5	.27	3.7	.31	3.2	.35	2.9
13			.17	5.9	.22	4.5	.26	3.8	.31	3.2	.36	2.8	.40	2.5
14					.25	4.0	.30	3.3	.34	2.9	.41	2.4	.45	2.2
15					.28	3.6	.34	2.9	.40	2.5	.46	2.2	.51	2.0
16					.32	3.1	.38	2.6	.44	2.3	.52	1.9	.58	1.7
17							.42	2.4	.49	2.0	.58	1.7	.64	1.6
18							.47	2.1	.55	1.8	.64	1.6	.71	1.4
19							.51	2.0	.60	1.7	.70	1.4	.79	1.3
20							.55	1.8	.66	1.5	.77	1.3	.87	1.2
21									.72	1.4	.85	1.2	.95	1.1
22									.78	1.3	.92	1.1	1.04	.96
23									.84	1.2	1.01	1.0	1.13	.88
24									.90	1.1	1.08	.92	1.22	.82
25									.97	1.0	1.16	.86	1.32	.76
26													1.42	.70
27													1.51	.66

[1] From "Forest Mensuration of White Pine in Massachusetts," by Harold O. Cook. The volumes, which were scaled by the Humphrey caliper rule for stacked cordwood, include bark, and are for the portion of the tree between a 6-inch stump and a minimum top diameter of 4 inches.

TABLE 29.—*Log rule for second-growth white pine.—Southern New Hampshire.*[1]

[Cut into both square and round-edged boards; circular saw, ¼-inch kerf.]

Diameter inside bark at small end of log.	Length of log (feet).			Basis (number of logs measured).
	10	12	14	
	Volume.			
Inches.	*Board feet.*	*Board feet.*	*Board feet.*	*Logs.*
3	5	7	9	167
4	8	10	12	429
5	13	15	17	530
6	18	21	24	606
7	24	28	33	613
8	30	36	42	542
9	38	46	52	456
10	47	56	65	395
11	56	68	80	290
12	66	81	97	248
13	77	96	115	202
14	89	112	134	168
15	102	130	155	144
16		149	176	104
17		169	198	97
18		189	222	64
19		211	247	40
20		235	275	41
21		260	304	17
22		284	333	11
23			364	9
24			398	4
Total.				5,177

[1] Prepared by Louis Margolin, Forest Service, in cooperation with the State of New Hampshire. Sixty per cent of the lumber sawed was round-edged and 40 per cent squared; 70 per cent 1-inch boards and 30 per cent 2½-inch plank.

Thickness of Bark.

Table 30 shows the thickness of bark on a radial section for white pine of various diameters in the Southern Appalachians. It also applies very generally throughout the tree's range.

Table 30.—*Thickness of bark—Southern Appalachians.*[1]

Diameter breast high.	Thickness of bark.	Diameter breast high.	Thickness of bark.	Diameter breast high.	Thickness of bark.	Diameter breast high.	Thickness of bark.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1	0.14	11	1.20	21	2.10	31	2.94
2	.28	12	1.30	22	2.20	32	3.04
3	.40	13	1.38	23	2.28	33	3.16
4	.52	14	1.44	24	2.36	34	3.28
5	.64	15	1.54	25	2.44	35	3.40
6	.74	16	1.64	26	2.52	36	3.50
7	.86	17	1.72	27	2.60	37	3.64
8	.96	18	1.84	28	2.68	38	3.76
9	1.02	19	1.94	29	2.76	39	3.90
10	1.10	20	2.02	30	2.86	40	4.04

[1] From measurements taken under the direction of F. E. Olmsted.

Yield Tables.

Table 31 shows the average yield per acre of white-pine stands of various ages in the Lake States. The trees were scaled by the Scribner Decimal C rule, and the figures are an average of a large number of acres. The figures are for virgin forest and not for second growth, and for this reason are greatly below the yield given for second-growth white pine in Table 6, page 23.

Table 31.—*Yield per acre, virgin forest—Minnesota.*[1]

Age.	Yield per acre.	Age.	Yield per acre.	Age.	Yield per acre.	Age.	Yield per acre.
Years.	*Board feet.*	*Years.*	*Board feet.*	*Years.*	*Board feet.*	*Years.*	*Board feet.*
50	8,000	90	23,500	130	46,000	170	70,300
60	12,500	100	28,000	140	53,000	180	75,500
70	16,700	110	33,500	150	59,300		
80	20,000	120	39,700	160	65,000		

[1] Data collected by H. H. Chapman. Computed by Scribner Decimal C rule.

Tables 32 and 33 show the yield per acre, in cords, of pure stands of second growth white pine in New England.

Table 32.—*Yield of fully stocked stands of second-growth white pine in New England.*[1]

Age of stand.	Average height.	Total trees per acre.	Merchantable trees per acre.	Yield per acre.	Age of stand.	Average height.	Total trees per acre.	Merchantable trees per acre.	Yield per acre.
Years.	*Feet.*	*Number.*	*Number.*	*Cords.*	*Years.*	*Feet.*	*Number.*	*Number.*	*Cords.*
10	5	2,220	....	....	40	54	690	540	38
15	9	1,700	....	....	45	62	510	460	45
20	14	1,600	....	....	50	68	400	380	53
25	22	1,310	400	11	55	72	300	300	65
30	32	1,090	510	21	60	76	260	260	80
35	45	885	620	30					

[1] From "The Natural Replacement of White Pine on Old Fields in New England," by S. N. Spring, Bulletin 63, Forest Service.

TABLE 33.—*Yield per acre of second-growth white pine in Massachusetts.*[1]

Age.	Quality I. 1-inch boards, in board feet.	Quality I. Cords.	Quality I. Cubic feet.	Quality II. 1-inch boards, in board feet.	Quality II. Cords.	Quality II. Cubic feet.	Quality III. 1-inch boards, in board feet.	Quality III. Cords.	Quality III. Cubic feet.
Years.									
25	10,825	25.1	2,080	6,750	16.4	1,300	3,975	10.8	750
30	19,900	44.0	3,750	12,500	31.2	2,740	7,500	18.2	1,400
35	31,150	60.4	5,420	24,400	49.0	4,375	16,950	35.8	3,035
40	40,650	70.6	6,590	32,800	58.0	5,300	25,200	46.2	4,080
45	49,350	78.0	7,420	40,600	64.8	6,075	32,100	51.8	4,785
50	55,150	84.2	8,035	46,500	70.0	6,725	37,550	56.6	5,475
55	59,650	89.2	8,575	50,550	74.8	7,200	42,100	60.8	6,015
60	63,600	93.4	9,075	53,200	79.2	7,655	44,550	64.6	6,340
65	67,050	97.2	9,550	56,600	83.0	8,050	46,150	68.4	6,550

[1] From "Forest Mensuration of the White Pine in Massachusetts," by Harold O. Cook. Based on measurements of 177 sample plots, one-quarter and one-eighth acre in size, in stands of different ages and qualities. Yields scaled by the use of volume tables 24, 26, and 27.

RELATION OF TAXES AND OTHER COSTS TO THE STUMPAGE VALUE AND THEIR EFFECT UPON LENGTH OF ROTATION.

Table 34, which is based on the stumpage prices in Table 11 and the cost data in Tables 12 and 13, gives the proportion of the taxes and other expenses to the stumpage value, and shows how the expenses, distance of haul, interest rate, and site quality affect the length of the financial rotation.

TABLE 34.—*Taxes and other expenses in per cent of the stumpage value, where distance from stand to local market permits a daily haul of 1,000 and 3,000 board feet of lumber per team.* (*See p.* 31.)

Interest rate.	Age.	Quality.	Daily haul per team=1,000 board feet. Taxes.	Other expenses when cost of formation is— $0	$6	$12	Daily haul per team=3,000 board feet. Taxes.	Other expenses when cost of formation is— $0	$6	$12
	Years.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
4 per cent..	50	I	25.7	17.1	36.2	55.4	26.7	9.9	20.9	31.9
		II	23.4	23.9	50.7	77.4	24.0	13.6	28.7	43.9
		III	22.2	37.8	80.0	122.2	21.2	21.1	44.6	68.2
	70	I	69.3	26.2	53.2	80.1	74.0	15.7	31.8	48.0
		II	63.5	33.7	68.2	102.7	66.1	19.9	40.4	60.8
		III	55.4	45.5	92.3	139.0	55.9	26.7	54.1	81.5
6 per cent..	50	I	34.0	45.6	95.1	144.7	34.5	26.3	54.9	83.5
		II	32.2	63.7	133.0	202.3	31.3	36.1	75.4	114.6
		III	33.6	100.6	210.0	319.5	29.1	56.1	117.2	178.3
	70	I	110.3	97.6	199.8	301.9	116.4	58.5	119.6	180.8
		II	101.3	125.2	256.3	387.3	102.9	74.1	151.7	229.3
		III	91.6	169.4	346.6	523.9	87.4	99.4	203.3	307.2

ADDITIONAL COPIES of this publication may be procured from the SUPERINTENDENT OF DOCUMENTS, Government Printing Office, Washington, D. C., at 15 cents per copy